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TENNESSEE REGIONAL ATMOSPHERIC
TRANSPORT STUDY - DATA SUMMARY VOLUME
LONG-RANGE TRANSPORT FIELD INTENSIVES
1979 AND 1980

AIR RESOURCES PROGRAM

TENNESSEE VALLEY AUTHORITY
Office of Natural Resources

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY -
DATA SUMMARY VOLUME
LONG-RANGE TRANSPORT FIELD INTENSIVES 1979 AND 1980

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SUMMARY

This Data Summary Volume presents pollutant measurements (both airborne and ground-based), quality control information, horizontal flux estimates, meteorological summaries, and air parcel trajectories for two regional field intensive studies. These two intensives were conducted during October-November 1979 and March-April 1980 over a large area in the southeastern United States.

Pollutants measured and reported in this volume include: total suspended particulate (TSP), SO_2 , NO_2 , NO , SO_4^{2-} , and NH_4^+ . Also reported are measurements of aerosol and gaseous light scattering, temperature, and dewpoint.

The intent of this volume is to report the data; no analysis is presented.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
DATA SUMMARY VOLUME
LONG-RANGE TRANSPORT FIELD INTENSIVES 1979 AND 1980

INTRODUCTION

Historically, when evaluating the impact of power plant emissions, the region of concern was the immediate vicinity (within 20 km) of the power plant, and the pollutants of concern were mainly particulates and sulfur dioxide (SO_2). In most scientific work relating to atmospheric transport of pollutants, little or no attention was given to the intermediate (20 to 100 km), regional (100 to 1000 km), or interregional (beyond 1000 km) transport of pollutants. Recently, however, emphasis has shifted to intermediate and regional transport of power plant emissions. Publication of the Prevention of Significant Deterioration (PSD) regulations (Federal Register, 1978) focused attention on the intermediate transport. Interest in the regional and interregional transport of pollutants was initiated by the gradually evolving sulfate (SO_4^{2-}) transport-transformation theory. This theory implies that remote primary emissions (particularly from power plants with tall stacks) are transformed into secondary particulate sulfates and nitrates and transported over long distances. Within the last 10 years, interest in regional transport has steadily increased, as indicated by numerous international publications (e.g., Bolin et al., 1971; Eliassen and Saltbones, 1974; Smith and Jeffrey, 1975; Bolin and Pearson, 1975; Altshuller, 1976; World Meteorological Organization, 1979).

During the same period, researchers compiled a growing list of adverse effects of exposure of the human population, biota, and materials to atmospheric particulates. In particular, acid sulfate particulates have been implicated in the health damage formerly attributed to SO_2 (EPA, 1974; Hausknecht and Ziskind, 1975). Other adverse environmental effects of atmospheric sulfates and nitrates include acidic deposition (wet/dry), with related adverse effects on the ecology of lakes, rivers, soils, and forests (Braekke, 1976; Likens, et al., 1979), and corrosion of materials (Yocom and Grappone, 1976). More recently, visibility reduction has been related to increases in atmospheric SO_4^{2-} levels (Trijonis and Yuan, 1978). Reduction in visibility and possible harmful health effects are of special concern for aerosols in the 0.1- to 1-micron (μm) size range. Sulfates are one of the more important contributors to atmospheric aerosols in this size range.

The problem with controlling sulfates and nitrates is that they are predominantly secondary pollutants transported to the receptor from usually unknown source regions, and little is known about the transport-transformation phenomenon. The transformation and long-range transport of these fine particulates from unknown sources make the problem of equity in control strategies especially acute. Thus, development of a physically realistic regional transport-transformation modeling technology is essential to developing an equitable control strategy.

Developing regional-scale modeling technology requires submodels for gas-to-particulate conversion processes and various removal processes.

Also, detailed information on the time-dependent regional emissions and diffusion and transport wind fields will be required to drive the model.

Highly accurate models would be complex because of the possible non-linear dependence of products on the source strength of primary emissions. Another potential problem is the dependence of the gas-to-particulate reaction on other trace atmospheric constituents, e.g., hydroxyl (OH) radicals, trace metals, water vapor, ozone (O_3), and ammonia (NH_3).

Also, biogenic (natural) sources of sulfur compounds are now being actively investigated (Adams, et al., 1980). It is possible that natural source regions may be major contributors to elevated background levels for gaseous and particulate sulfur.

To address some of these problems and other basic research questions related to atmospheric chemistry and interregional transport, the Tennessee Valley Authority (TVA), in cooperation with the U.S. Environmental Protection Agency (EPA), is conducting field experiments on individual power plant plumes and regional airmasses. Since the spring of 1976, TVA has conducted four long-range transport (LRT) experiments over large areas of the southeastern United States. Results from these studies are being used to create a regional data base. This data base will describe pollutant characteristics as related to climatological, geographical, and emission variations. In addition, future regional models will be evaluated against this data base.

Using ground-level and aircraft platforms, 3- to 5-week field intensives were conducted. Measurements were made of gaseous and particulate sulfur and nitrogen compounds, O_3 , light scattering aerosols, total

suspended particulates (TSP), and basic meteorological parameters. The earliest two studies are described in a TVA/EPA Interagency report by Crawford and Reisinger, 1980. That report describes both the summary and analysis of data from the spring 1976 and summer 1977 studies.

This report presents the sampling methodology, airborne, and ground-based measurement and quality control data, calculated mean boundary layer concentrations and flux values (the product of integrated boundary layer concentration times the mean wind speed), and a meteorological summary of the weather and air parcel trajectories for the fall 1979 and spring 1980 LRT field intensives.

SAMPLING METHODOLOGY AND QUALITY CONTROL

Two long-range transport studies--one from mid-October to early November 1979 and the second in late March and April 1980--were conducted over a large region of the southeastern United States. A Rockwell Aero-commander twin-engine aircraft (figure 1) was used to fly approximately 150-km horizontal traverses perpendicular to the mean wind direction. A schematic of a typical sampling pattern is shown in figure 2. Typically, two levels within the boundary layer were sampled using onboard continuous gas analyzers and filters. Occasionally a background (or above inversion) traverse was also flown. The specific parameters sampled, the instruments or filter materials used and the quality control data are presented in tables 1 through 3. Figures 3a and 3b present a schematic of the aircraft instrument and probe layout and particulate probe assembly. The total suspended particulate (TSP) and Nuclepore filter holders were

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Figure 1. Aircraft used in 1979 and 1980 field intensive studies

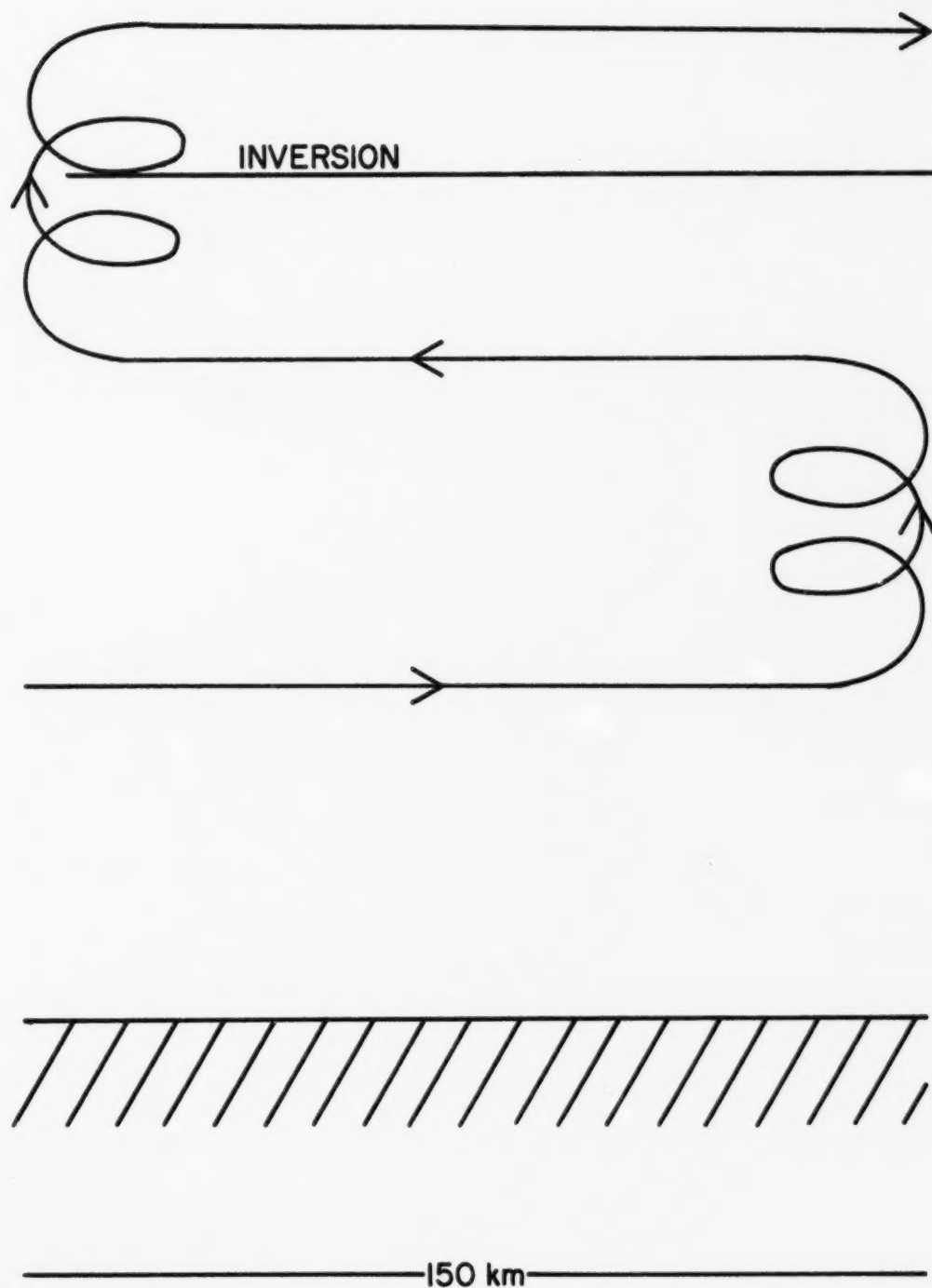


Figure 2. Schematic of typical sampling pattern.

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TABLE 1. AIRBORNE DATA COLLECTION AND QUALITY CONTROL - FILTER MEASUREMENTS^a

Parameter	Analysis method	Filter material	Avg. blank ($\mu\text{g}/\text{filter}$)	Analytical accuracy ^a			No. of replicates
				Concentration ^b ($\mu\text{g}/\text{filter}$)	Recovered (%)	Precision (%)	
SO_2	Ion chromatography (Tennessee Valley Authority, 1980b)	Treated Whatman - 41 cellulose (Healy and Atkins, 1975)	1.71	-	-	-	59
				6.7	80	13	4
				10.0	85	5	2
				16.7	95	6	2
				33.9	95	3	4
				66.7	101	4	2
SO_4^{2-}	Ion chromatography (Tennessee Valley Authority, 1980a)	Millipore (Fluoro- pore) 1.0 μm pore size, 47 mm diam.	0.27	-	-	-	35
				5	98	3	7
				10	99	10	7
				20	103	5	6
				50	98	6	3
NH_4^+	Ion chromatography (Tennessee Valley Authority, 1980a)	Millipore (Fluoro- pore) 1.0 μm pore size, 47 mm diam.	0.24	-	-	-	9
				3.7	92	7	4
				7.5	97	2	7
				18.8	84	21	2
Particulate (TSP)	Gravimetric	Millipore (Fluoro- pore) 3 μm pore size, 13 mm diam.	8,583 ^c	-	-	-	7
				-32.5 ^d	-	4	6

^aAverage measured field study mass (in μg) per filter: SO_2 = 15.2, SO_4^{2-} = 21.6, NH_4^+ = 3.6, Part. = 107.

^bConcentrations for SO_2 , SO_4^{2-} , and NH_4^+ applied by syringe using a solution of $(\text{NH}_4)_2\text{SO}_4$ or Na_2SO_4 in 25% isopropanol.

Concentration for SO_2 applied and analyzed as SO_4^{2-} but reported here as SO_2 .

^cSeven blank filters each weighed six times gave an average blank weight of 8.583 mg with an average standard deviation of ± 0.004 mg.

^dConcentration estimated from six separate weighings both before and after ambient sampling.

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TABLE 2. AIRBORNE DATA COLLECTION AND QUALITY CONTROL - INSTRUMENT MEASUREMENTS

Parameter	Detector	Instrument	Lower detectable limit	Zero and span frequency checks
NO-NO _x	Chemiluminescence	Monitor Labs 8440	8 ppb	Daily
O ₃	UV absorption	Dasibi 1003AAS	2-4 ppb	Daily
b _{scat}	Nephelometer	MRI 1150B	10 ⁻⁵ m ⁻¹	Daily
Mass flow	Thermal conductivity	Matheson 8160	5% of full scale	-
Temperature	Thermistor	Custom	-	a
Dewpoint temperature	Chilled mirror	Cambridge 137-C3	-	a

^aCalibrated before and after each field intensive.

TABLE 3. GROUND-BASED HIGH-VOLUME^a DATA COLLECTION AND QUALITY CONTROL

Parameter	Analysis method	Filter material	Analytical accuracy				No. of replicates
			Avg. blank (mg/filter)	Concentration (mg/filter)	Recovered (%)	Precision (%)	
Particulate (TSP)	Gravimetric	Gelman (Spectrograde) glass fiber	-	-	-	10	15
SO ₄ ²⁻	Methylthymol Blue (EPA, 1978)	Gelman (Spectrograde)	<1	-	-	-	b
		glass fiber	-	16	102	13	42

^aGeneral Metal Works Model 2310 high-volume samplers with flow controllers.

^bNumerous values reported by manufacturer and TVA Laboratory Branch.

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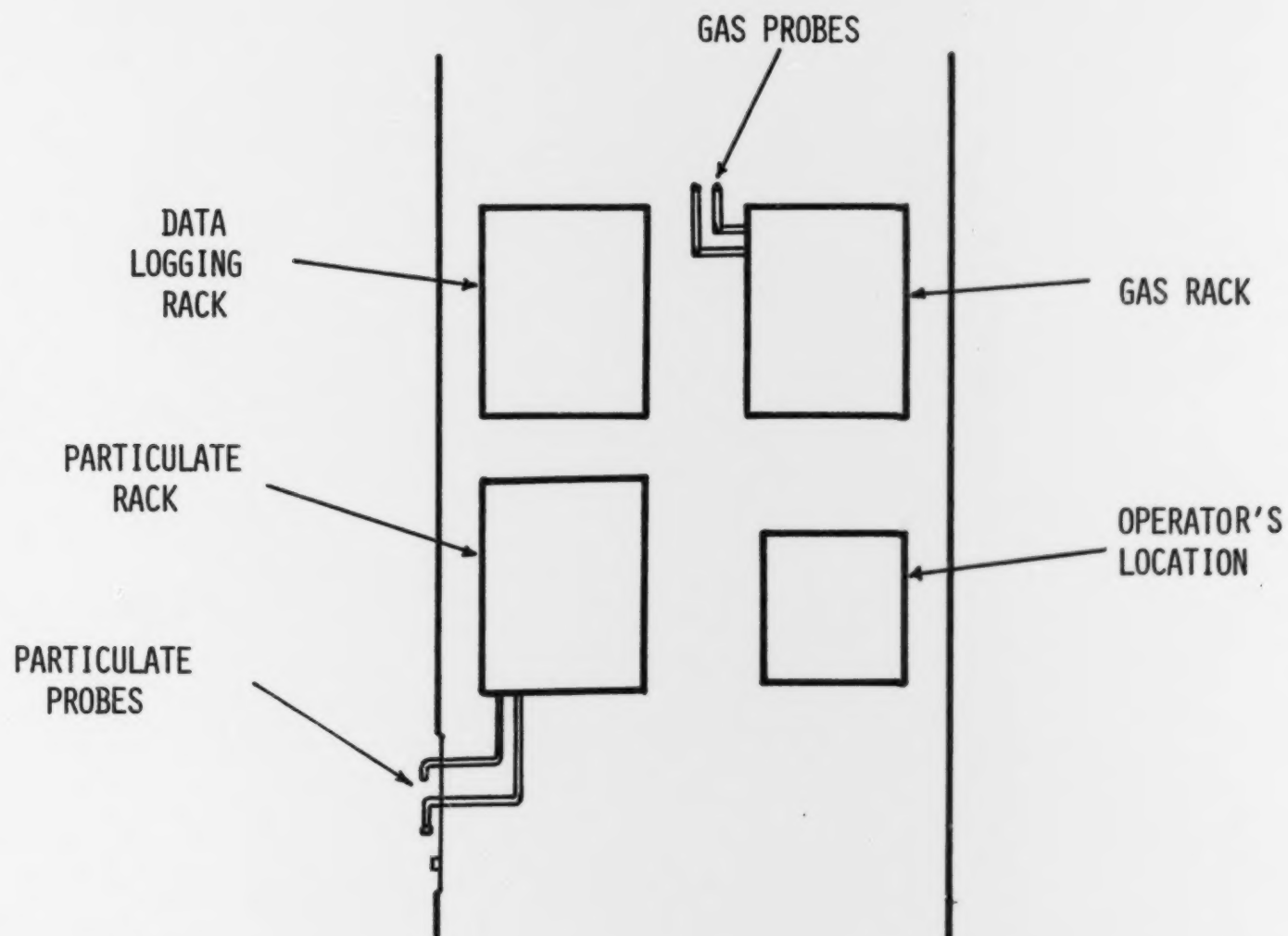


Figure 3a. Aircraft instrument and probe layout.

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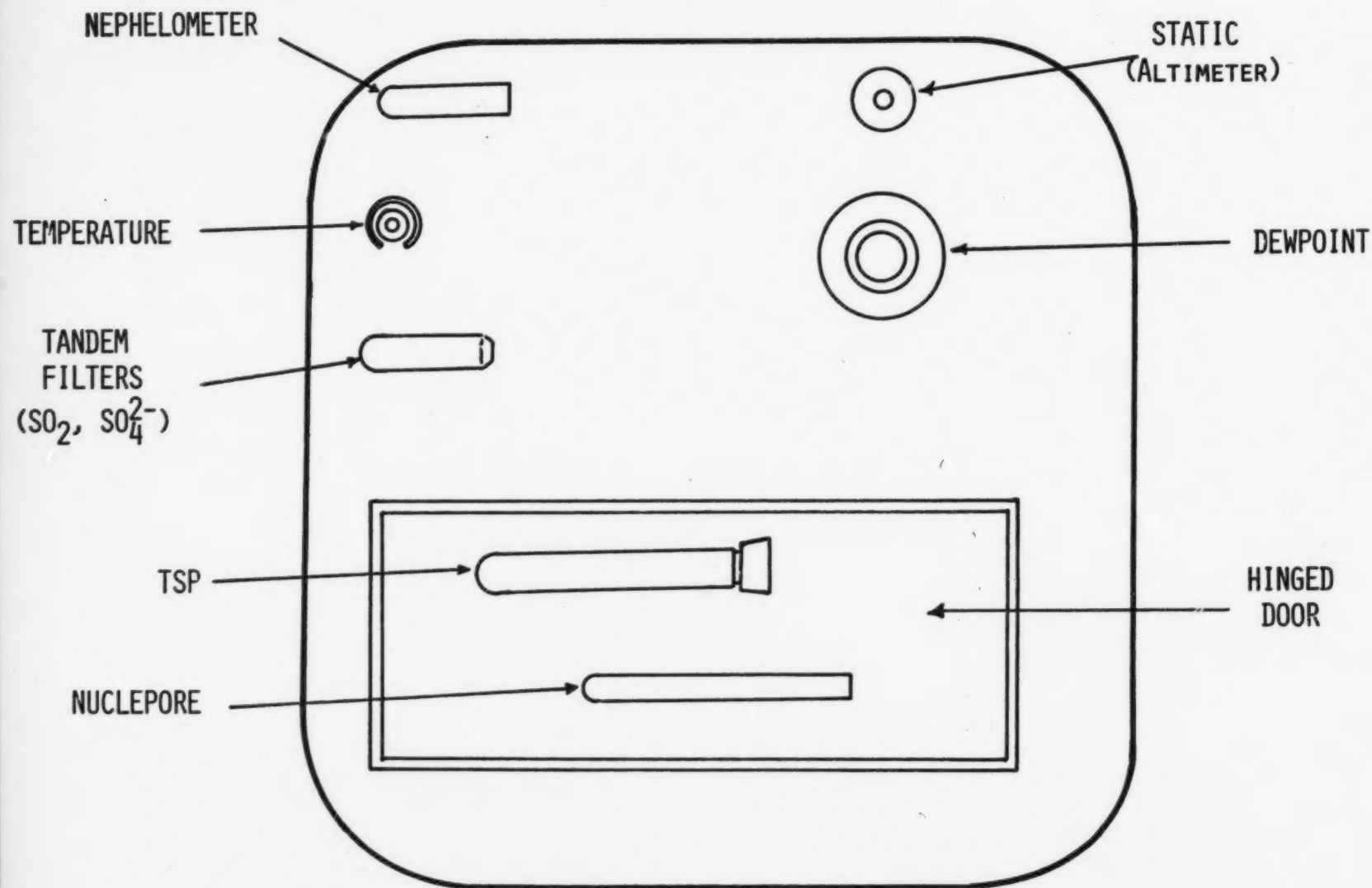


Figure 3b. Exterior probe assembly.

directly attached to the exterior probe assembly shown in figure 3b while the tandem filter pack was attached to the cabin side of the aircraft. Elemental analysis (using proton-induced X-ray emissions) and scanning electron microscope data were obtained from 0.4 μm pore sized Nuclepore filters. However, due to analytical delays, these data are not reported here. The tandem filter pack consists of a 1 μm pore sized fluoropore prefilter for particle collection followed by a pair of treated Whatman - 41 filters for SO_2 collection. The fluoropore and treated Whatman - 41 filters were separated in the stainless steel holders by stainless steel screens and rubber O-ring seals. Stainless steel inlets were used for all gaseous and particulate collection. Matheson mass flow meters were used to obtain volume measurements for all particulate samples.

The intent of the sampling was to describe the changes in pollutant form, concentration, and flux as various air parcels progressed across the southeastern United States. Ideally, the same air parcel was sampled at various times and locations in Lagrangian or parcel following sampling. The measured concentrations from the aircraft flights are presented in appendix A. Also, ground-based high-volume filter measurements of TSP and SO_4^{2-} were made at a number of sites in the southeastern United States (see figure 4). The ground-based high-volume measurements are presented in appendix B.

AVERAGE MIXED-LAYER CONCENTRATIONS

Because of sampling limitations, the mean mixed-layer concentration ($\bar{C}$) for any given pollutant was estimated from a few (two to four)

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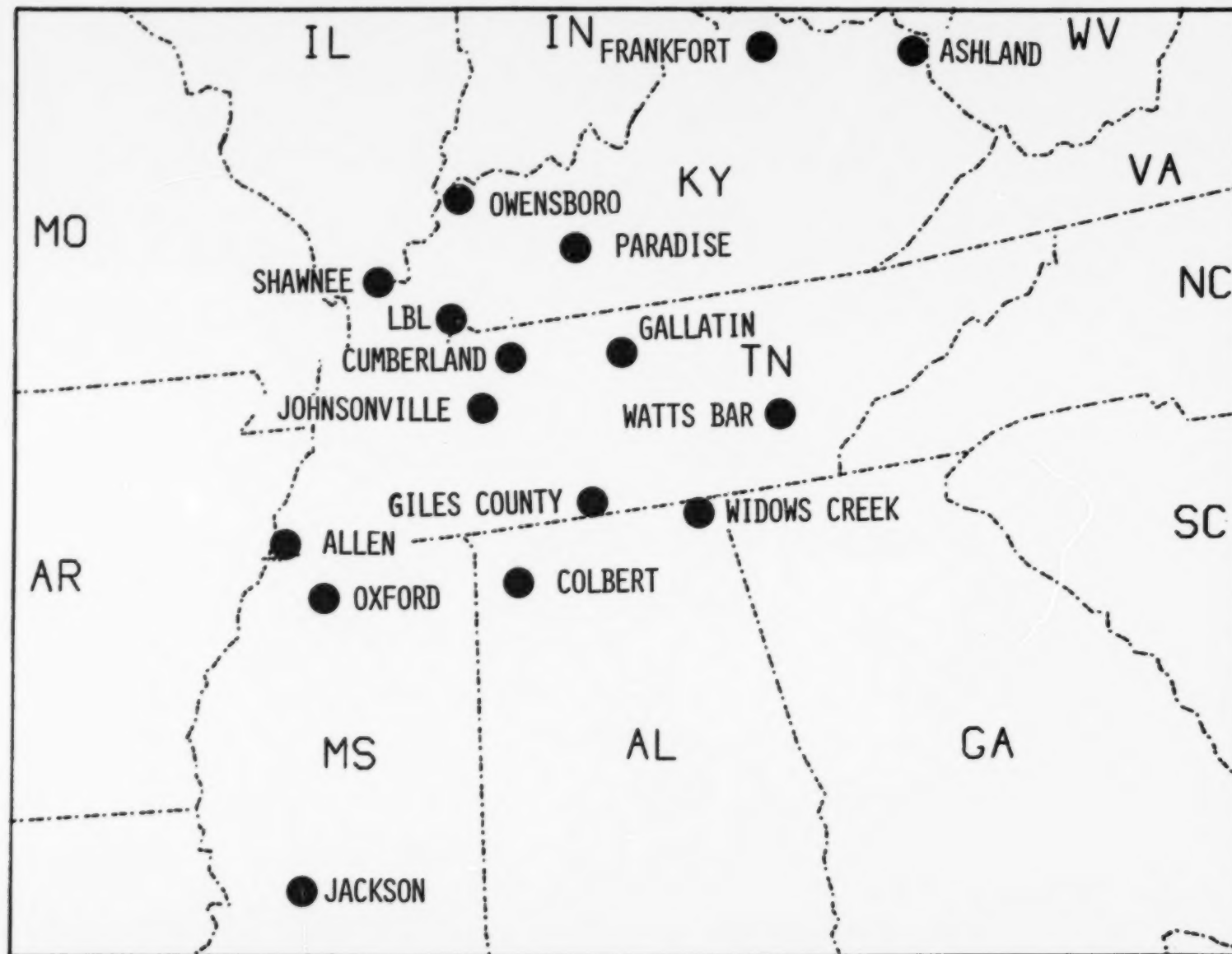


Figure 4. Ground-based high-volume measurement sites.

discrete horizontally integrated traverses and "typical" pollutant profile shapes. These profiles (figures 5 through 12) were generated by normalizing all sets of airborne measurements isolated in space and time. These figures show that, except for the 1979 SO₂ data, concentration profiles were quite flat, with little vertical gradient, indicating good vertical mixing.

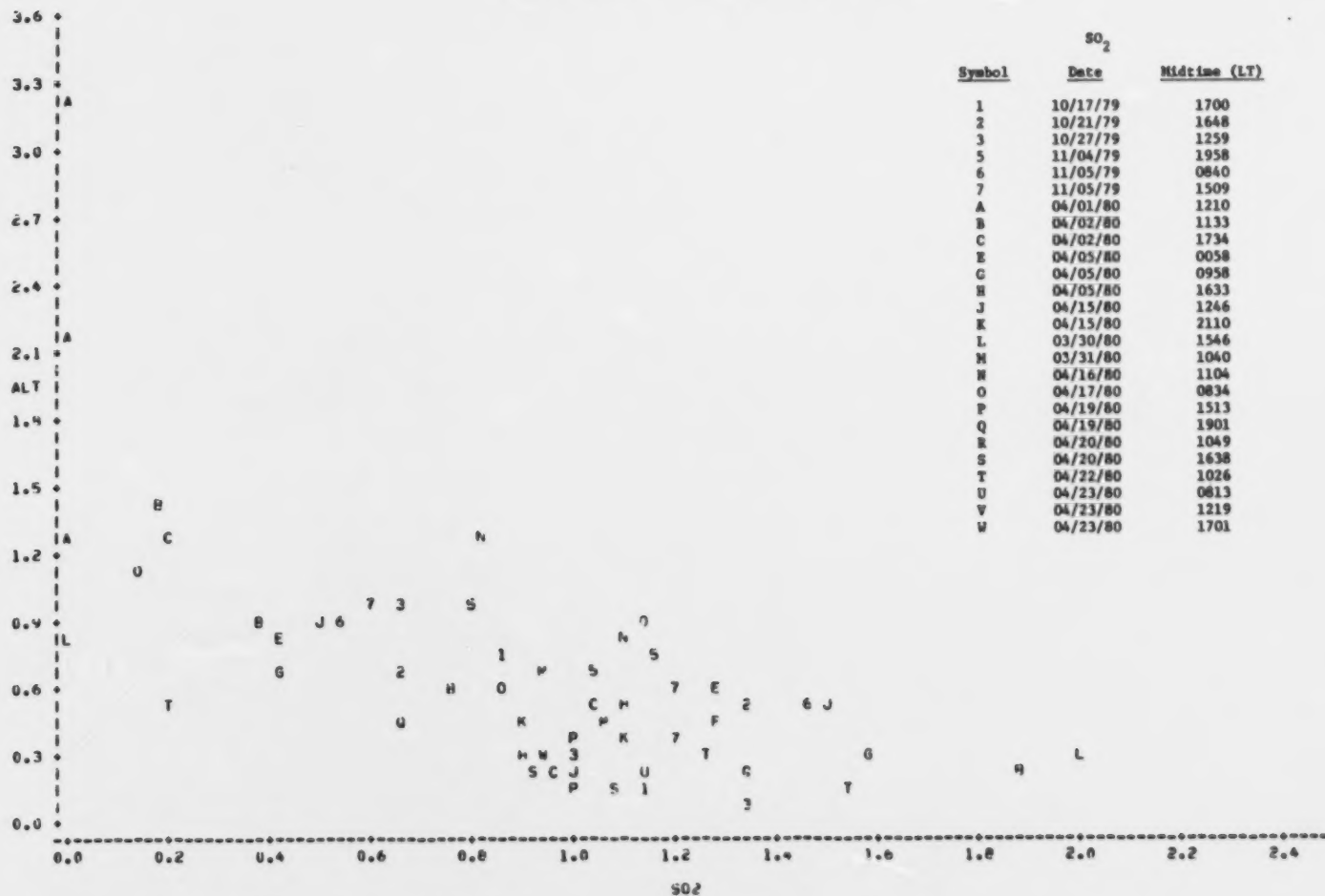
All measurements were made above any radiation inversions. Thus, on the few days when early measurements were made, pollutant concentrations for SO₂, SO₄²⁻, NH₄⁺, and O₃ within any radiation inversion layer were estimated as described by Crawford and Reisinger, 1980. Otherwise, except for the 1979 SO₂ data, concentration estimates were obtained using a simple vertically weighted averaging scheme. Here, discrete horizontal measurements contributed to the layer average concentration estimate proportionally to their location within the mixed layer. For the 1979 SO₂ data, a linear best fit based on the normalized vertical profile was used to describe average concentrations above any radiation inversions.

The estimated average mixed-layer concentrations obtained using the above averaging scheme are given in appendix C. This appendix presents concentration estimates only for those days when sufficient measurements were available to quantify spatial and/or temporal variations.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*SO₂ SYMBOL IS VALUE OF EVENT



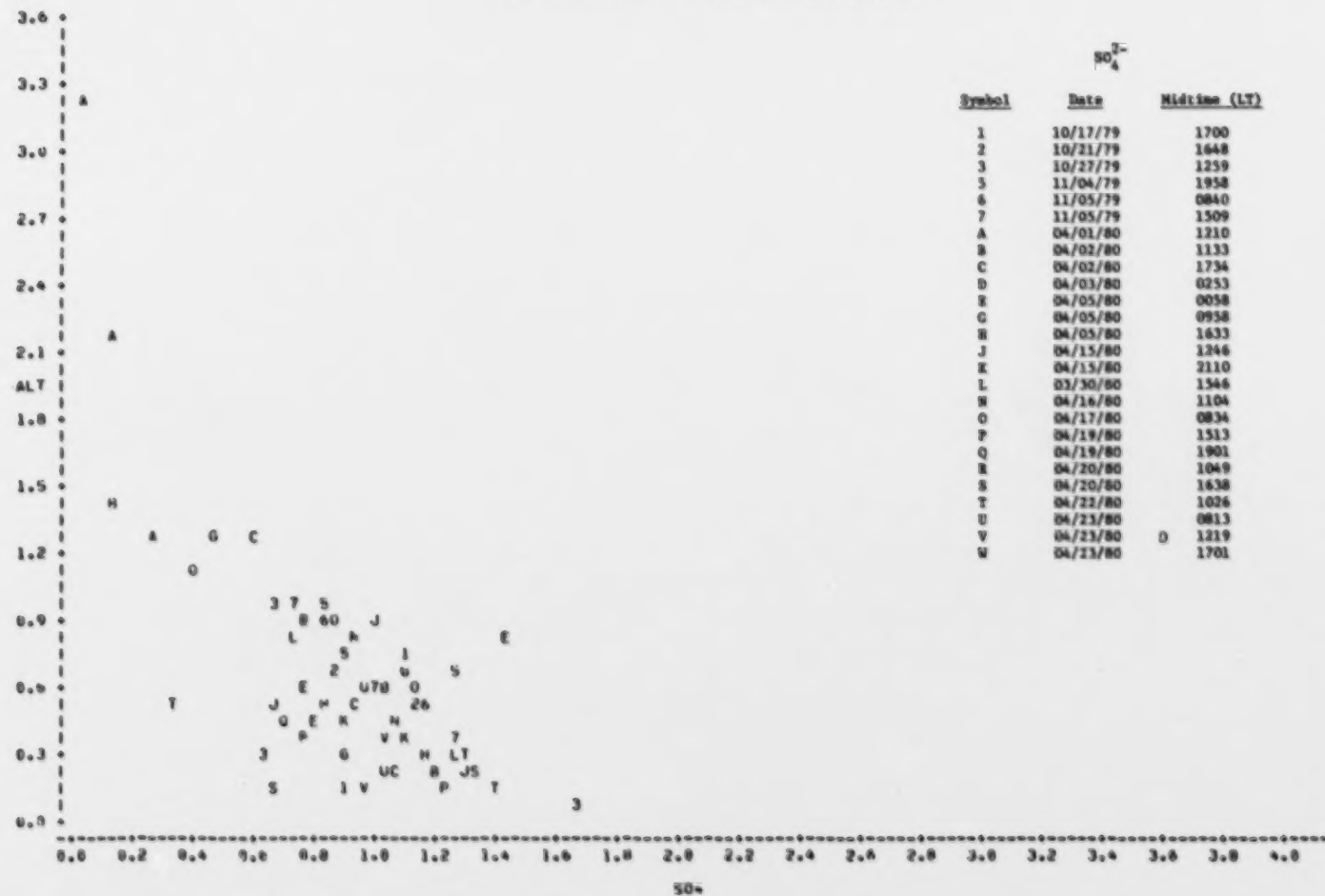
NOTE: 13 OBS HAD MISSING VALUES 8 OBS HIDDEN

Figure 5. Normalized SO₂ profile.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*504 SYMBOL IS VALUE OF EVENT



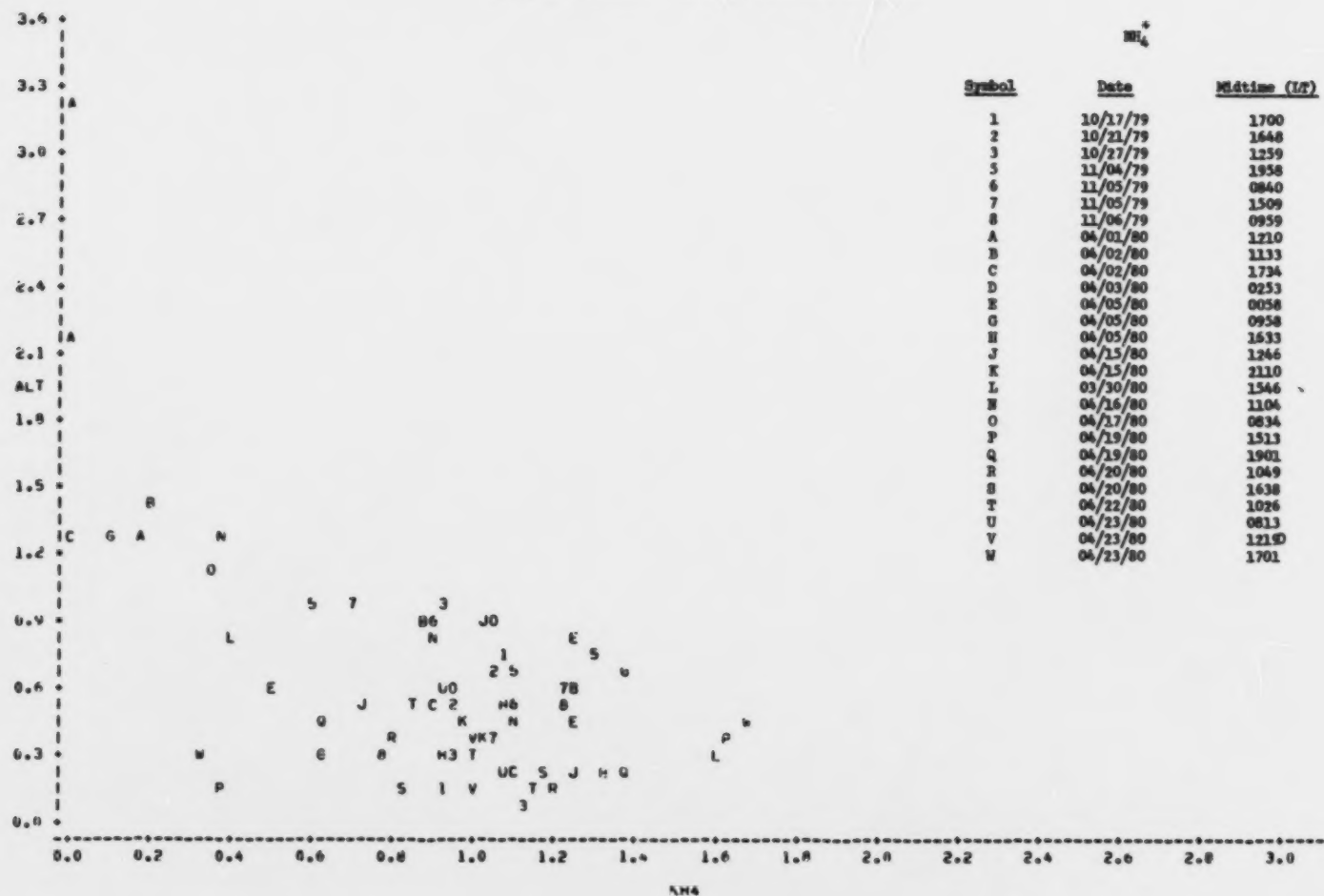
NOTE: 14 OBS HAD MISSING VALUES 6 OBS HIDDEN

Figure 6. Normalized sulfate profile.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*NH4 SYMBOL IS VALUE OF EVENT



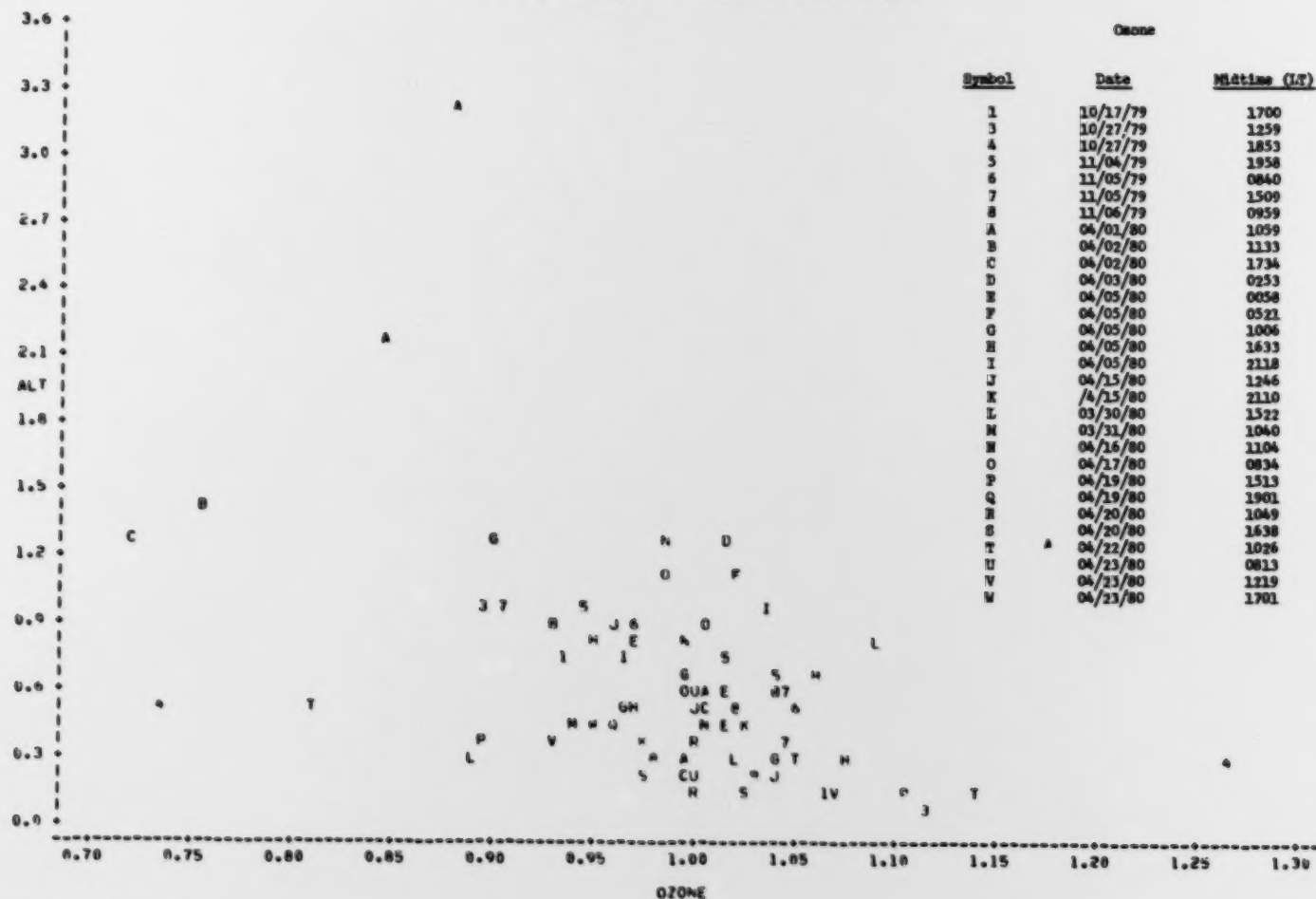
NOTE: 12 OBS HAD MISSING VALUES

Figure 7. Normalized ammonium profile.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*OZONE SYMBOL IS VALUE OF EVENT



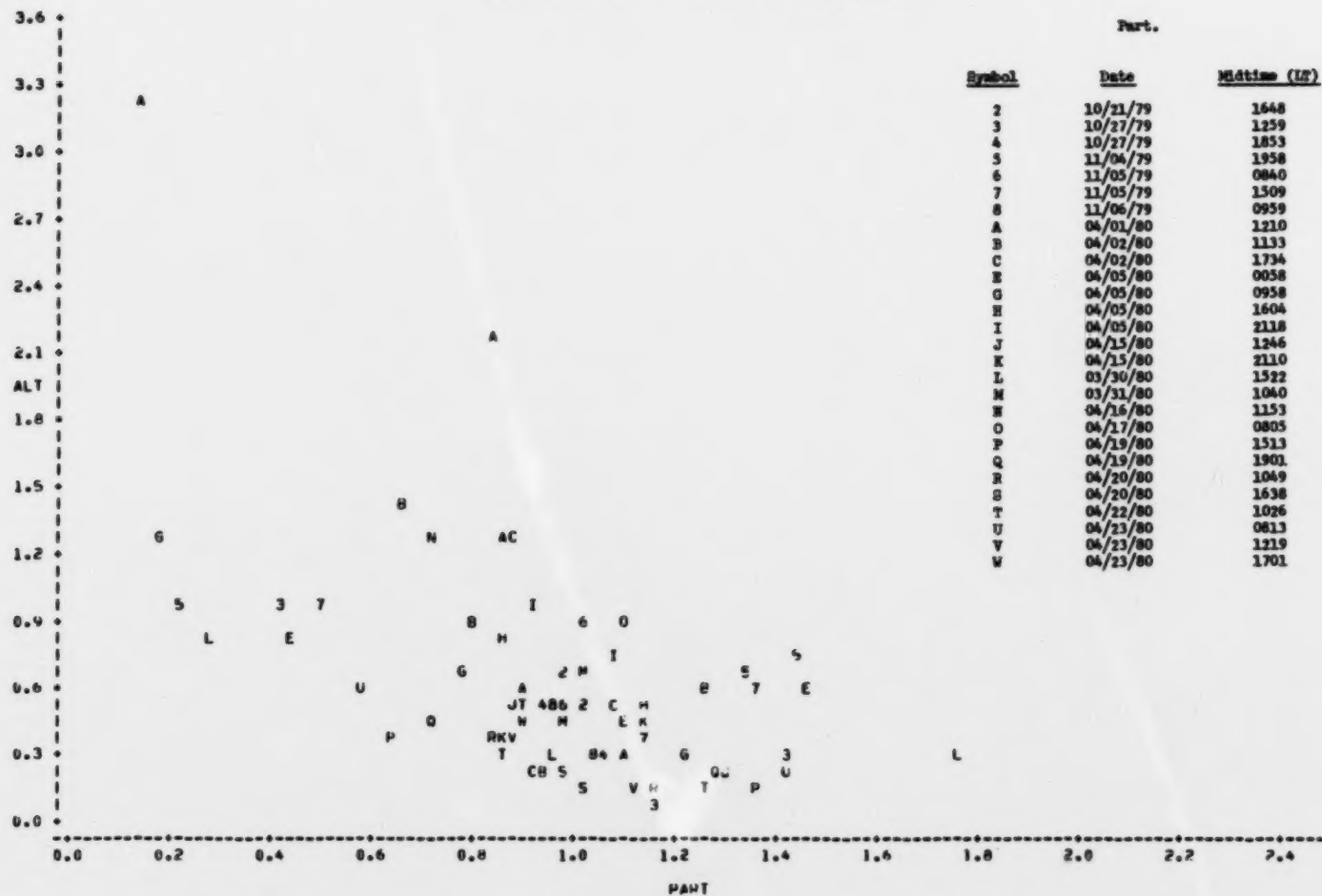
NOTE: 2 OBS HAD MISSING VALUES 3 OBS HIDDEN

Figure 8. Normalized ozone profile.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*PART SYMBOL IS VALUE OF EVENT



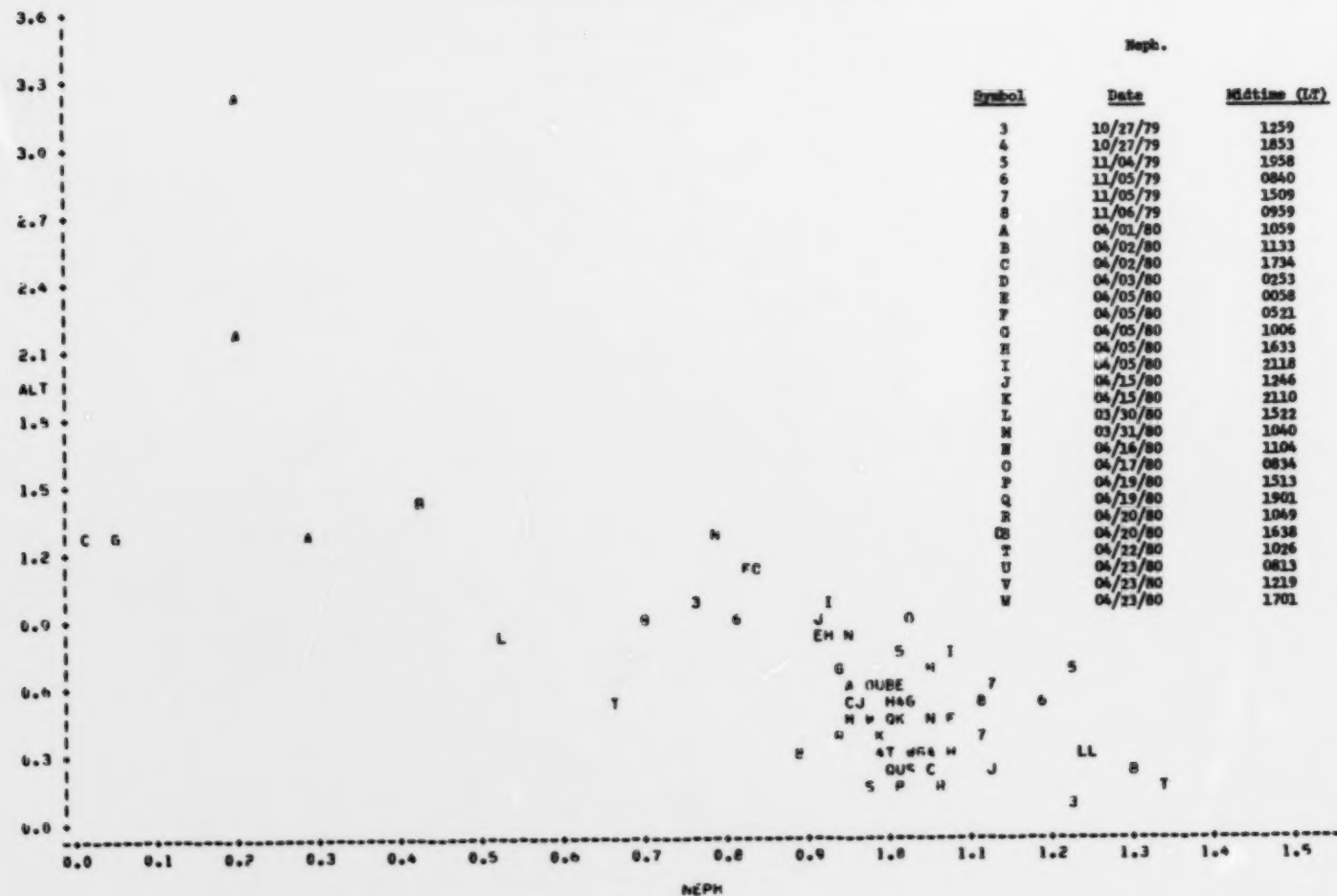
NOTE: 9 OBS HAD MISSING VALUES 3 OBS MIDWEN

Figure 9. Normalized total suspended particulate profile.

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*NEPH SYMBOL IS VALUE OF EVFNT



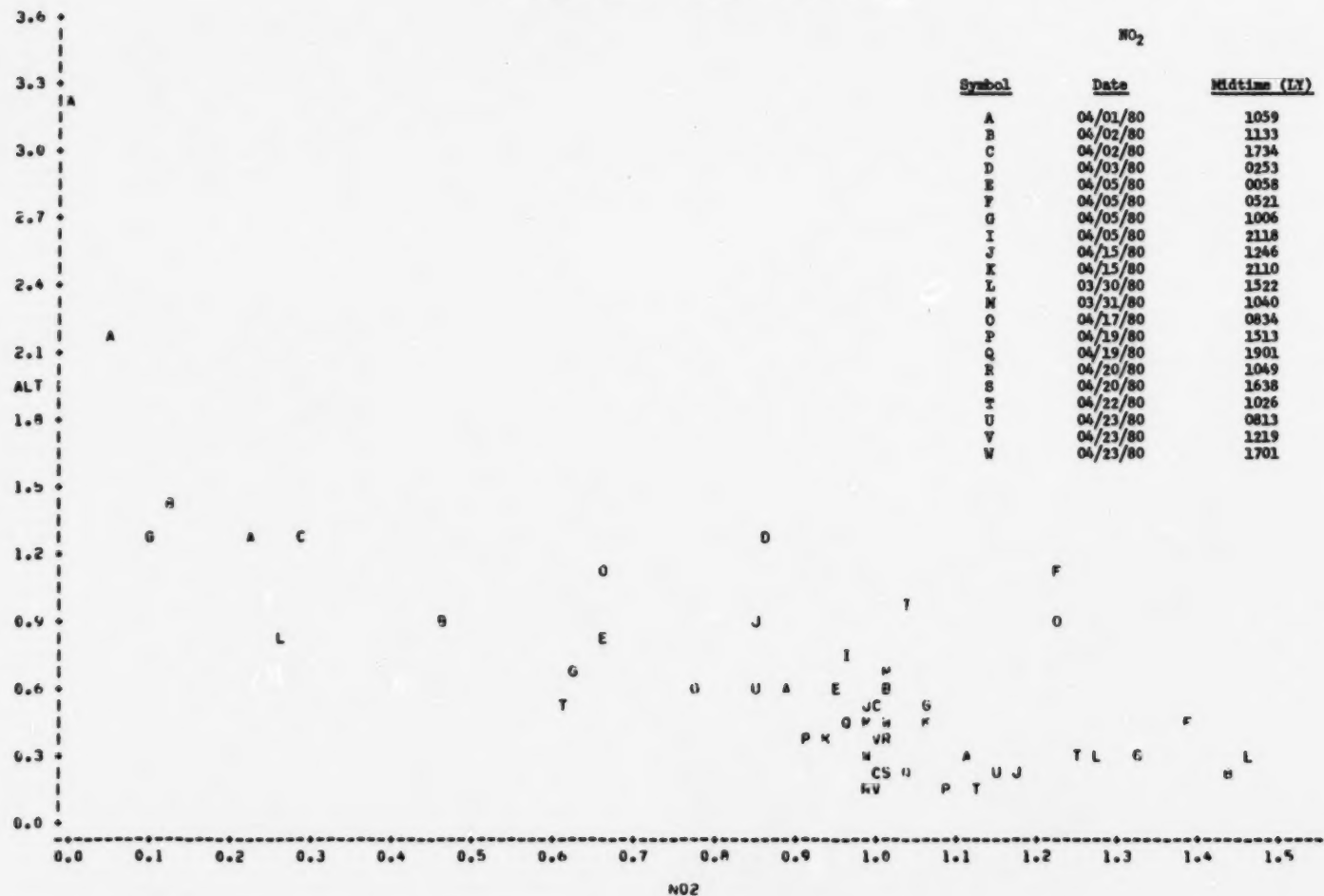
NOTE: 4 OBS HAD MISSING VALUES 6 OBS HIDDEN

Figure 10. Normalized b_{scat} profile.

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1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*NO2 SYMBOL IS VALUE OF EVENT

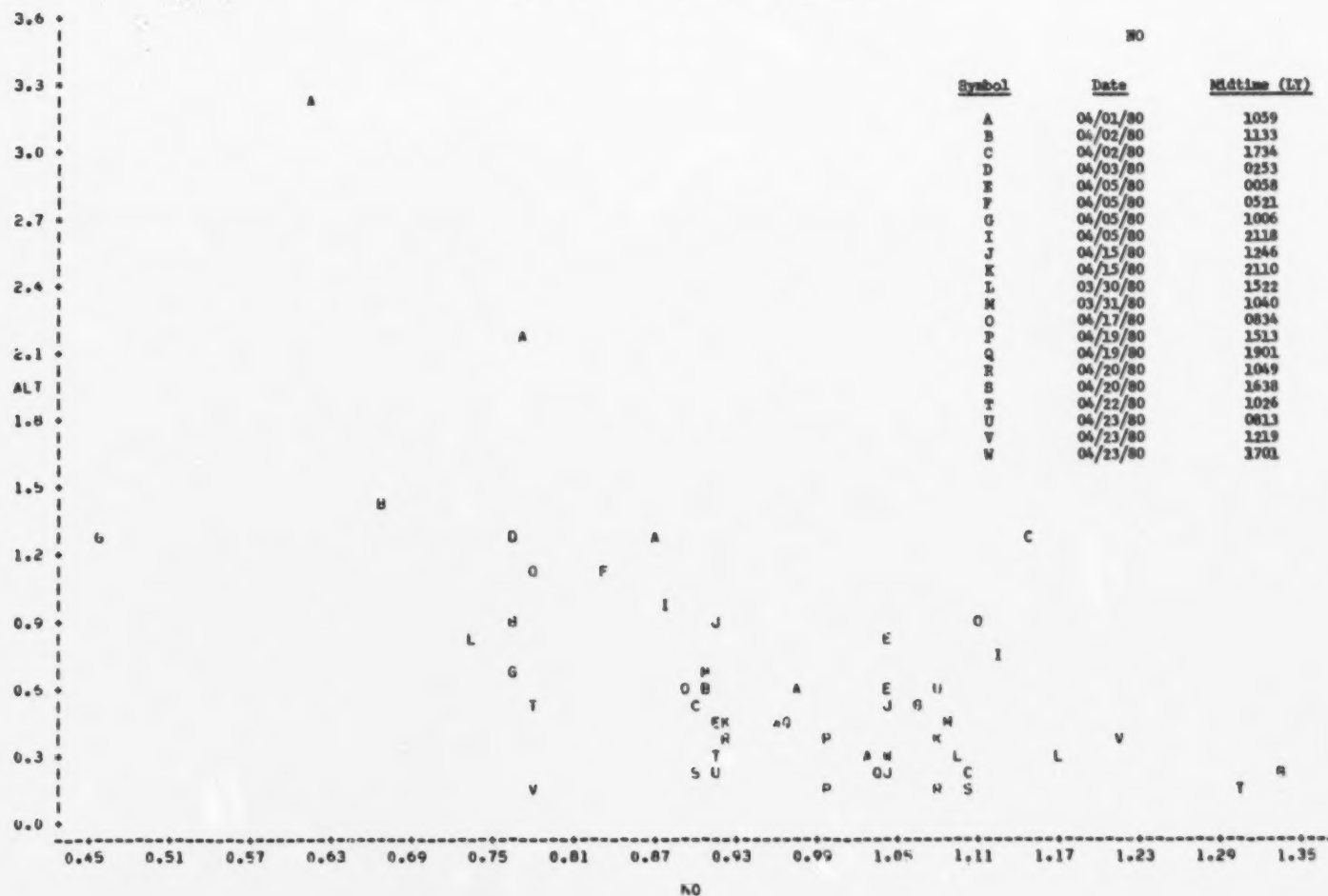


NOTE: 25 OBS HAD MISSING VALUES 1 OBS HIDDEN

Figure 11. Normalized nitrogen dioxide profile.

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
1979 AND 1980 NORMALIZED AIRBORNE MEASUREMENT DATA

PLOT OF ALT*NO SYMBOL IS VALUE OF EVENT



NOTE: 25 OBS HAD MISSING VALUES 1 OBS HIDDEN

Figure 12. Normalized nitric oxide profile.

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FLUX CALCULATIONS

Measurements of regional mass transport (or flux) of a pollutant are very useful for assessing not only the impact of the studied area on itself and adjacent regions, but also the impact of adjacent regions on the studied region. Ideally, pollutant flux can be defined at any location, but measurements at inflow and outflow locations relative to a study region are the most informative. An inflow measurement defines the input of an upwind region on the study area, whereas an outflow measurement defines the combined input of the upwind and study regions on the downwind region. The net input of a studied area on a downwind region is defined by differences in these measurements (i.e., outflow minus inflow). This difference, when complemented with meteorological and source information, is also useful in studying characteristics and mechanisms of the long-range transport phenomenon.

Pollutant flux can be defined at a point, over a line, or through a plane. The appropriate method for assessing regional impact is the pollutant flux through a plane. This is defined as:

$$F_1(x,t) = \iint C_1 U dy dz / (H \cdot L), \quad (1)$$

where

F_1 = transported mass of pollutant species 1 per unit area
per unit time.

C_1 = concentration of pollutant species 1,

U = transporting wind speed (ideally normal to the measurement plane),

H = height of the plane,

L = length of the plane.

x = position coordinate in the downwind direction,

y = position coordinate in the crosswind direction,

z = position coordinate in the vertical direction.

Unfortunately, equation (1) is impossible to evaluate rigorously because C_1 and U vary, not only as a complex unknown function of position coordinates x, y, and z, but also as a function of time t. Therefore, assumptions must be made about the spatial and temporal variations of C_1 and U.

By assuming that variation in time is "slow" compared with the time scale required for the measurement (about two hours) and the horizontal inhomogeneity can be integrated out by long horizontal sampling traverses (about 150 km), then equation (1) can be approximated as:

$$F_1 = \frac{1}{H} \bar{C}_R \bar{U} H_R + \bar{C}_S \bar{U} (H_S - H_R) + \bar{C}_B \bar{U} (H_{\max} - H_S), \quad (2)$$

where

H = average mixing height for all study days,

$\bar{C}_R$ = average concentration through H_R ,

$\bar{U}$ = average wind speed through H_S ,

H_R = height of radiation inversion,

$\bar{C}_S$ = average concentration from H_R to H_S ,

H_S = height of subsidence inversion,

$\bar{C}_B$ = background concentration,

$H_{\max}$ = daily maximum mixing height.

Figure 13 illustrates how these fluxes were piecewise integrated. For early morning measurements, F_1 was approximated by the sum of three parts: (1) within the morning radiation inversion; (2) between the radiation and subsidence inversions; and (3) between the morning subsidence height and $H_{\max}$. Thus, on days when H_S was less than the afternoon's maximum mixing height ($H_{\max}$), a correction for $\bar{C}_B$ (the above subsidence inversion mean concentrations) from H_S to $H_{\max}$ was used in the F_1 approximation. This correction allows for mass conservation when comparing mass flux during the diurnal cycle and is especially important when comparing early morning to midday measurements. Actual measurements of $\bar{C}_B$ were used when possible; otherwise, the study average $\bar{C}_B$ was used. When the morning subsidence inversion height is greater than the afternoon mixing height, mass conservation is assumed to result from meteorological subsidence of superior air. Thus, no corrections are made under these conditions. Also, so that intercomparison between days can be made, the flux values for all days have been normalized to the grand mean subsidence inversion height measured during each study, H (i.e., for 1979, $H = 1440$ m; and for 1980, $H = 1880$ m).

Estimates of $\bar{U}$ were obtained using the air parcel trajectories for the spatial and temporal center of the sampling traverses. These trajectories were produced using data obtained from the National Weather Service (NWS) Boundary Layer Model (Long et al., 1978) and are presented along with meteorological summaries in appendix E.

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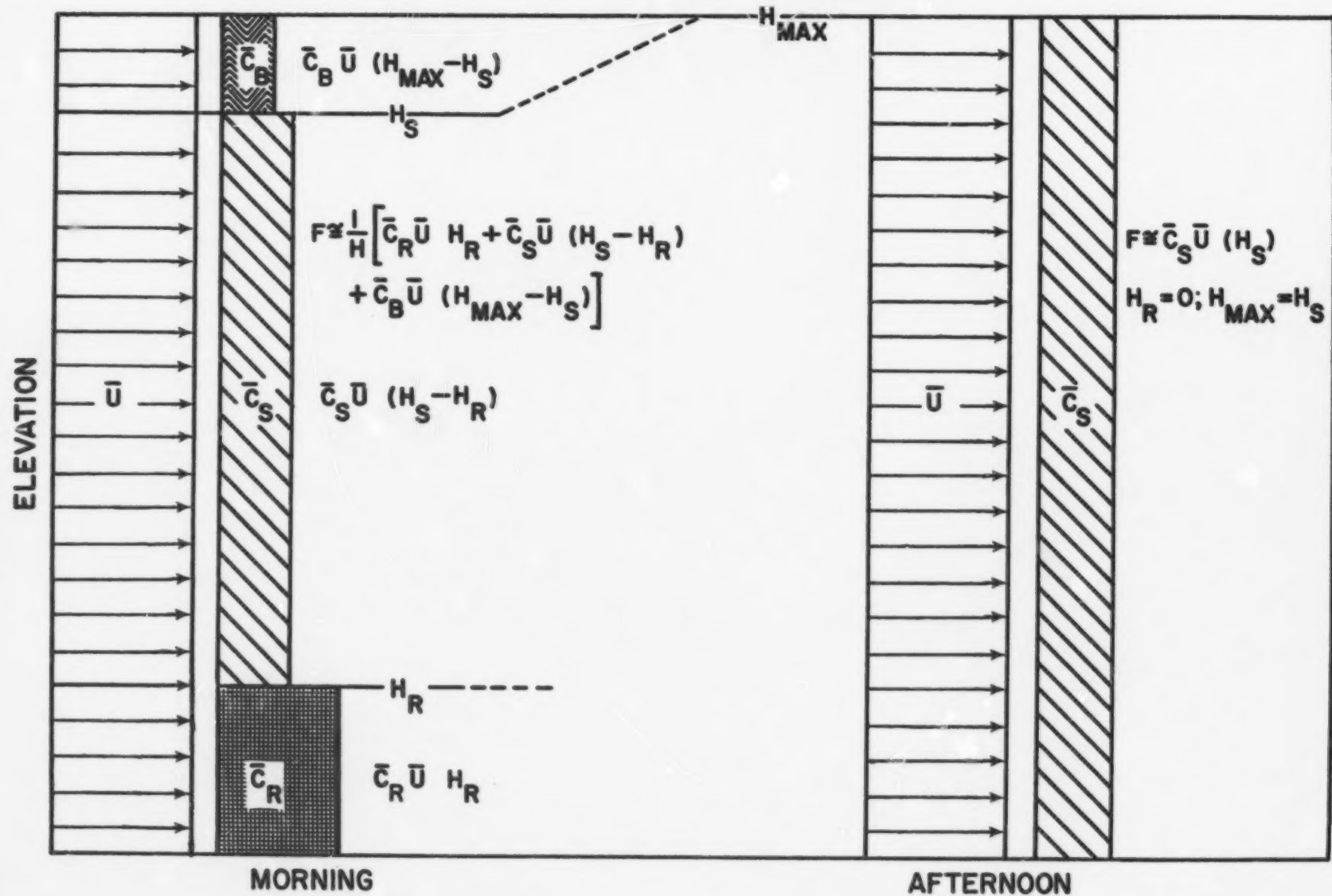


Figure 13. Schematic of typical flux calculation procedure.

For both the 1979 and 1980 studies, the TVA or NWS station(s) closest to and/or most representative of the airmass sampled was used to estimate actual mixing height. To determine the best estimate of the actual average mixing height for a group of measurements, the representative sounding was plotted, and the near-surface temperature measured at midsampling time was used to find the dry adiabatic intersection of the sounding. Variations can possibly occur when estimating the actual mixing height, especially during midmorning, which is the time when radiation inversions usually dissipate. However, on the average, this method is a good approximation to the true mixing height (Holzworth, 1972).

Appendix D contains flux values for those days when flux calculations were deemed appropriate.

REFERENCES

- Adams, D. F., Farwell, S. O., Robinson, E., and Pack, M. R. 1980. Bio-genic sulfur emissions in the SURE region. Final report. Pullman, Washington: Washington State University, September 1980. EPRI No. EA-1516, EPRI Project No. RP 856-1.
- Altshuller, A. P. 1973. Atmospheric sulfur dioxide and sulfate--distribution of concentration at urban and nonurban sites in the United States. Environ. Sci. Technol. 7:709-712.
- Bolin, B., Granat, L., Ingelstam, L., Johannesson, M., Matesson, E., Oden, S., Rodhe, H., and Tamm, C. O. 1971. Air pollution across national boundaries. The impact of sulfur in air and precipitation. Sweden's Case Study for the United Nations Conference on the Human Environment, P. A. Norstedt and Sons, Stockholm, Sweden.
- Bolin, B., and Pearson, C. 1975. Regional dispersion and deposition of atmospheric pollutants with particular application to sulfur pollution over western Europe. Tellus 24:281-310.
- Braekke, H., Ed. 1976. Impact of acid precipitation on forest and fresh-water ecosystems in Norway. SNSF Fagrapport FRG, Aas-NCH, Norway.
- Crawford, T. L., and Reisinger, L. M. 1980. Transport and transformation of sulfur oxides through the Tennessee Valley region. EPA-600/7-80-126, Environmental Protection Agency, Washington, D.C.
- Eliassen, A., and Saltbones, J. 1974. Decay and transformation rates of SO₂, as estimated from emission data, trajectories, and measured air concentrations. Atmos. Environ. 9:425-429.
- Environmental Protection Agency. 1974. Health consequences of sulfur oxides--a report from CHES, 1970-1971. EPA-650/1-74-004, Environmental Protection Agency, Washington, D.C.
- Environmental Protection Agency. 1978. Tentative Method for the determination of sulfates in the atmosphere (Automated Technicon II Methylthymol Blue Procedure). Environmental Monitoring and Support Laboratory, Research Triangle Park, N.C.
- Federal Register. 1978. 43(43):8962-9059.
- Hausknecht, D. F., and Ziskind, R. A. 1975. Effects of sulfur oxides on the lung: An analytical base. Research Project 205, prepared for Electric Power Research Institute, Palo Alto, California.

- Healy, C., and Atkins, D.H.F. 1975. The determination of atmospheric sulfur dioxide after collection on impregnated filter paper. AERE No. R7956, Environmental and Medical Sciences Division, AERE, Harwell, England.
- Holzworth, G. C. 1972. Mixing heights, wind speeds, and potential for urban air pollution throughout the contiguous United States. EPA Pub. No. AP-101, Environmental Protection Agency, Washington, D.C.
- Likens, G. E., Wright, R. F., Galloway, J. N., and Thomas, T. J. 1979. Acid rain. Scientific American 241(4):43-51.
- Long, P. E., Shaffer, W. A., Kemper, J. E., and Hicks, F. J. 1978. The state of the techniques development laboratory's boundary layer model: May 24, 1977. NOAA Tech. memorandum NWS TOL 66.
- Smith, F. B., and Jeffrey, G. H. 1975. Airborne transport of sulphur dioxide from the United Kingdom. Atmos. Environ. 9:643-659.
- Tennessee Valley Authority. 1980a. Atmospheric sulfate, ammonium nitrogen, and nitrate on Teflon (Fluoropore) filters. Quality Assurance Procedure No. NRS-LB-AP-10.200.3 Rev. 0, Laboratory Branch, Chattanooga, Tennessee.
- Tennessee Valley Authority. 1980b. Sulfur dioxide in air (ion chromatography). Quality Assurance Procedure No. NRS-LB-AP-10.381.5 Rev. 1, Laboratory Branch, Chattanooga, Tennessee.
- Trijonis, J., and Yuan, K. 1978. Visibility in the Northeast--long-term visibility trends and visibility/pollutant relationships. EPA 600/3-78-075, Environmental Protection Agency, Research Triangle Park, North Carolina.
- World Meteorological Organization. 1979. Papers presented at the WMO symposium on the long-range transport of pollutants and its relation to general circulation including stratospheric/tropospheric exchange processes. WMO-No. 538, Secretariat of the World Meteorological Organization, Geneva, Switzerland.
- Yocom, J. E., and Grappone, N. 1976. Effects of power plant emissions on materials. EC-139, Summary report prepared for Electric Power Research Institute, Palo Alto, California.

APPENDIX A

AIRBORNE MEASUREMENT DATA - 1979 AND 1980

ABBREVIATIONS AND UNITS FOR APPENDIX A

DATE: Date of sample, month, day, year

S_TIME: Airborne sampling start time, local hours, minutes

END_TIME: Airborne sampling end time, local hours, minutes

S_CLASS: T = within mixed-layer traverses, B = above mixed layer
traverses

PART: Total suspended particulate mass loading, $\mu\text{g m}^{-3}$

NEPH: Nephelometer, $b_{\text{scat}}, 10^{-4} \text{ m}^{-1}$

NH₄: Ammonium particulate, $\mu\text{g m}^{-3}$

SO₄: Sulfate particulate, $\mu\text{g m}^{-3}$

SO₂: Sulfur dioxide, $\mu\text{g m}^{-3}$

OZONE: Ozone, $\mu\text{g m}^{-3}$

NO_x_NO: Total gaseous nitrogen oxides expressed as nitric oxide,
 $\mu\text{g m}^{-3}$

NO₂_NO: Nitrogen dioxide expressed as nitric oxide, $\mu\text{g m}^{-3}$

NO: Nitric oxide, $\mu\text{g m}^{-3}$

AIR_AGE: Ratio of total particulate sulfate (as S) to the total sulfur
(both particulate and gaseous)

T: Air temperature, °C

DP: Air dewpoint temperature, °C

FROM_LAT: Latitude coordinate (°N) of traverse start point

FROM_LON: Longitude coordinate (°W) of traverse start point

TO_LAT: Latitude coordinate (°N) of traverse end point

TO_LON: Longitude coordinate (°W) of traverse end point

MH_M: Mixing height, m above ground level

ALT_M: Sampling altitude, m above ground level

BEST DOCUMENT AVAILABLE

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 AIRBORNE MEASUREMENT DATA

OBS	DATE	S_TIME	END_TIME	S_CLASS	PART	NEPH	NH4	S04	S02	OZONE	NOX_NO	AIR_AGE	T	DP	FROM_LAT	FROM_LON	TO_LAT	TO_LON	NH4_M	ALT_M
1	101779	1500	1725	T	.	.	2.5	10.4	8	90	.	0.47	24	.	34.77	88.12	34.63	87.33	1709	305
2	101779	1730	1800	T	.	.	2.9	13.4	6	79	.	0.60	16	.	34.77	88.12	34.63	87.33	1709	1220
3	101979	1324	1403	T	.	1.7580	3.8	15.2	12	52	4	0.46	12	.	34.75	87.62	30.00	90.50	2378	1901
4	101979	1730	1805	T	.	2.0930	.	.	88	5	.	20	.	31.58	86.70	31.35	88.60	2378	915	
5	101979	1920	1854	T	.	1.9160	4.5	12.0	15	82	6	0.35	13	.	31.35	88.60	31.22	87.62	2378	1829
6	102179	905	947	R	58	.	0.6	1.9	4	52	3	0.24	16	10	34.58	86.47	34.57	86.92	610	1372
7	102179	954	1029	T	123	.	1.2	5.8	14	53	6	0.22	22	18	34.55	87.05	34.60	88.48	610	457
8	102179	1506	1555	T	194	.	1.2	5.4	20	77	5	0.15	24	16	37.23	86.06	37.77	87.95	1524	762
9	102179	1610	1650	T	185	.	1.3	4.0	10	.	.	0.21	.	.	37.77	87.95	36.97	86.42	1524	1067
10	102179	1725	1830	H	.	.	0.7	0.9	2	.	.	0.23	15	.	36.97	86.42	34.75	87.62	1524	1982
11	102779	859	1001	T	37	0.5607	1.5	3.9	12	99	6	0.18	18	3	33.23	87.62	32.33	88.75	1372	765
12	102779	1146	1222	T	95	0.5496	1.0	5.4	4	111	6	0.47	25	16	29.00	90.00	29.50	92.00	1372	152
13	102779	1236	1321	T	116	0.4475	0.9	2.1	3	99	5	0.32	23	15	29.50	92.00	29.00	90.00	1372	457
14	102779	1336	1412	T	35	0.3420	0.8	2.2	2	89	5	0.42	16	2	29.00	90.00	29.50	92.00	1372	1372
15	102779	1651	1725	T	169	1.2400	.	.	154	10	.	21	12	30.99	90.79	31.00	92.00	1372	758	
16	102779	1739	1804	T	194	1.1960	2.0	4.7	6	160	10	0.34	23	14	31.00	92.00	30.99	90.79	1372	457
17	102779	2019	2050	R	16	0.1548	0.5	0.4	1	51	3	0.21	13	-7	32.32	90.07	34.75	87.62	1372	2287
18	102879	641	714	T	.	1.1600	.	.	98	7	.	18	14	36.00	89.00	34.75	87.62	687	457	
19	110479	1346	1917	T	42	0.6372	1.5	4.2	9	100	5	0.31	11	-3	35.00	88.00	33.50	89.00	1410	915
20	110479	1928	2001	T	45	0.5288	1.8	4.5	10	98	5	0.23	9	-4	33.50	89.00	35.00	88.00	1410	1095
21	110479	2013	2039	T	7	0.3987	0.8	4.1	7	31	4	0.28	8	-9	35.00	88.00	33.50	89.00	1410	1372
22	110479	2044	2110	H	18	0.2005	0.4	2.3	7	94	3	0.18	12	-9	33.50	89.00	34.78	87.62	1410	1677
23	110579	519	552	R	.	0.2444	.	.	69	3	.	8	-9	35.88	87.94	36.00	89.40	1524	2591	
24	110579	437	708	T	79	0.4858	1.4	5.3	13	94	6	0.21	7	-8	36.50	89.50	36.50	87.50	1524	1372
25	110579	717	751	T	75	0.7112	1.7	7.2	36	102	9	0.12	11	-3	36.50	87.50	36.50	89.50	1524	762
26	110579	1017	1043	R	60	0.2059	0.4	1.7	6	69	3	0.16	3	-9	37.22	88.42	34.75	87.62	1372	2591
27	110579	1343	1421	T	87	0.8134	2.2	7.4	18	119	10	0.22	14	-2	34.39	88.49	34.39	86.47	1220	452
28	110579	1430	1505	T	103	0.8149	2.5	5.7	15	119	9	0.17	14	-3	34.39	86.47	34.39	88.49	1220	762
29	110579	1517	1554	T	38	0.5587	1.4	4.2	9	103	7	0.24	11	-9	34.39	88.49	34.39	86.47	1220	1220
30	110579	1635	1635	R	.	0.2859	.	.	75	4	.	12	-9	34.39	86.47	34.77	87.62	1220	1982	
31	110679	933	955	T	176	0.9391	2.3	5.5	5	52	9	.	6	5	37.26	86.29	37.44	87.46	1463	762
32	110679	1005	1026	T	189	0.7478	1.4	.	13	50	8	.	6	5	37.44	87.46	36.97	86.42	1463	457

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
1980 AIRBORNE MEASUREMENT DATA33

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY
 1980 AIRBORNE MEASUREMENT DATA

U H S	U A T E	S T I M E	E N O T I M E	C L A S S	P A R T	N E P H	N H 4	S O 4	S O 2	O Z O N E	N O X N O	N O 2 N O	N O	A I R - T A G E	T P	D P	F R O M - L A T	F R O M - L O N	T O - L A T	T O - L O N	M H - M	A L T - M
49	41740	1438	1523	T	147	1.0020	1.1	3.7	10	178	8	6	2	0.20	21	13	35.82	89.42	36.08	87.38	1677	457
50	41940	1411	1510	T	221	1.0930	0.4	14.2	6	167	6	5	2	0.61	24	16	31.11	92.35	31.04	91.17	1799	305
51	41930	1515	1620	T	106	1.0700	1.7	8.6	6	135	5	4	2	0.49	21	14	31.11	92.35	30.60	92.33	1799	610
52	41940	1749	1858	T	87	1.2540	2.4	11.3	6	148	6	4	2	0.56	23	18	29.57	92.47	29.57	90.83	1372	305
53	41940	1902	2018	T	48	1.2430	1.1	5.9	3	137	5	4	1	0.57	21	17	29.57	92.47	29.57	90.83	1372	610
54	42040	952	1053	T	139	1.5220	3.2	14.3	9	152	8	6	2	0.51	22	17	30.58	92.50	29.37	90.63	1738	305
55	42040	1036	1156	T	102	1.3390	2.1	8.6	9	152	7	6	2	0.39	20	16	29.37	90.63	30.58	92.50	1738	610
56	42080	1515	1633	T	113	1.2450	1.9	6.4	7	171	7	5	2	0.38	25	19	29.88	92.53	29.17	90.88	2591	305
57	42040	1642	1803	T	109	1.3230	2.7	12.6	6	142	7	5	1	0.58	21	15	29.88	92.53	29.17	90.88	2591	610
58	42180	1016	1143	T	101	1.3480	1.8	9.9	6	152	9	7	2	0.52	25	18	29.60	92.33	29.60	92.33	2134	61
59	42140	1148	1247	T	113	1.2540	2.2	11.4	5	153	7	6	1	0.60	26	18	29.60	92.33	29.60	92.33	2134	61
60	42180	1438	1630	T	168	1.3280	2.6	12.3	5	162	6	5	1	0.62	26	16	29.60	92.33	29.60	92.33	2134	153
61	42130	1836	2036	T	108	0.7619	0.8	5.4	5	188	3	2	1	0.42	12	-1	30.42	91.69	34.75	87.61	2530	2287
62	42280	850	953	T	201	1.4400	0.8	19.9	16	142	7	5	2	0.45	24	14	35.07	89.20	33.42	87.03	3048	457
63	42240	1000	1056	T	137	1.0820	0.7	18.5	13	131	7	5	1	0.49	21	10	33.42	87.03	35.07	89.20	3048	915
64	42290	1102	1156	T	143	0.7079	0.6	4.6	2	101	4	3	1	0.61	17	5	35.07	89.20	33.42	87.03	3048	1677
65	42340	711	812	T	103	1.2190	0.7	11.3	3	146	5	4	1	0.72	22	14	35.00	90.51	36.57	90.51	1585	915
66	42330	816	917	T	256	1.2630	0.8	12.1	4	146	6	5	1	0.67	25	19	36.57	90.51	35.00	90.51	1585	305
67	42380	1112	1217	T	211	1.2970	0.7	14.7	7	141	7	6	1	0.58	22	15	34.92	89.05	37.12	87.83	3048	1067
68	42340	1224	1324	T	269	1.3190	0.7	13.8	7	162	6	5	1	0.57	29	17	37.12	87.83	34.92	89.05	3048	467
69	42340	1534	1845	T	96	0.7604	0.5	5.1	2	112	4	3	1	0.63	14	5	34.75	87.61	34.93	85.80	3048	2287
70	42380	1602	1659	T	317	1.2240	0.3	16.5	8	170	6	5	1	0.58	25	14	34.93	85.80	37.28	85.80	3048	915
71	42340	1702	1805	T	260	1.1540	1.6	9.1	9	154	6	5	1	0.40	21	12	37.28	85.80	34.93	85.80	3048	1372

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APPENDIX B

GROUND-BASED MEASUREMENT DATA - 1979 AND 1980

ABBREVIATIONS AND UNITS FOR APPENDIX B

DATE: Sampling date, month, day, year

SITE: Sampling site name

TSP: Total suspended particulates mass loading, $\mu\text{g m}^{-3}$

SO₄: Sulfate particulates, $\mu\text{g m}^{-3}$

STIME: Ground-based sampling start time, local hours, minutes

ETIME: Ground-based sampling end time, local hours, minutes

(ETIME = 1200 refers to subsequent day)

LAT: Latitude coordinate (°N) of sampling site

LON: Longitude coordinate (°W) of sampling site

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 MI-VOL DATA

DATE=102179

Obs	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
1	ALLEN	91	8.0	900	2400	35.07	90.13
2	COLBERT	22	7.8	823	2400	34.74	87.84
3	CUMBERLAND	38	9.2	900	2400	34.38	87.64
4	GALLATIN	28	10.1	900	2400	34.33	86.40
5	GILES COUNTY	28	9.4	900	2400	33.28	86.90
6	JOHNSONVILLE	31	8.8	900	2400	34.02	87.99
7	L&L	31	9.4	839	2400	34.79	88.07
8	PARADISE	23	8.1	900	2400	37.27	86.99
9	SHAWNEE	34	7.2	713	2400	37.13	88.77
10	WATTSBAR	30	12.4	900	2400	35.40	84.79

DATE=102779

Obs	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
11	ALLEN	70	9.3	0	2400	35.07	90.13
12	ASHLAND	117	13.0	1200	1200	34.47	82.67
13	COLBERT	30	8.8	0	2400	34.74	87.84
14	CUMBERLAND	43	9.6	1	2400	34.38	87.64
15	FRANKFORT	83	10.3	0	2400	34.18	84.92
16	GALLATIN	47	8.6	0	2400	34.33	86.40
17	GILES COUNTY	49	10.3	1	2400	33.28	86.90
18	JOHNSONVILLE	48	10.3	0	2400	34.02	87.99
19	L&L	47	12.1	1	2400	34.79	88.07
20	OWENSBORO	71	11.2	0	2400	37.77	87.17
21	OXFORD	44	10.8	0	2400	34.37	89.52
22	SHAWNEE	87	10.7	1	2400	37.13	88.77
23	WIDOWSCREEK	42	12.8	0	2400	34.87	85.76

DATE=102879

Obs	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
24	ALLEN	40	9.7	800	2400	35.07	90.13
25	COLBERT	17	6.1	819	2400	34.74	87.84
26	CUMBERLAND	42	13.8	800	2400	34.38	87.64
27	GALLATIN	23	7.8	800	2400	34.33	86.40
28	GILES COUNTY	27	8.7	800	2400	33.28	86.90
29	JOHNSONVILLE	27	8.4	800	2400	34.02	87.99
30	L&L	47	19.2	800	2400	34.79	88.07
31	PARADISE	33	14.2	800	2400	37.27	86.99
32	SHAWNEE	46	8.9	800	2400	37.13	88.77
33	WATTSBAR	22	11.2	943	2400	35.40	84.79
34	WIDOWSCREEK	44	13.1	800	2400	34.87	85.76

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 HI-VOL DATA

DATE=110579

OBS	SITE	TSP	SO ₄	STIME	ETIME	LAT	LOH
35	ASHLAND	164	17.4	0	2400	38.47	82.67
36	FRANKFORT	77	12.1	0	2400	38.18	84.92
37	CHATTANOOGA	88	10.0	0	2400	37.77	87.17

BEST DOCUMENT AVAILABLE

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1980 HI-VOL DATA

DATE=40480

UNS	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOX
1	40480	ALLEN	17	4.2	800	1800	35.07	90.13
2	40480	CUMHENT	25	10.4	800	1800	34.74	87.84
3	40480	CUMHENTLAND	13	11.4	800	1800	34.38	87.64
4	40480	FRANKFORT	29	22.9	800	1800	34.18	84.92
5	40480	GALLATIN	23	17.4	800	1800	34.33	86.40
6	40480	GILESCOUNTY	20	11.2	800	1800	35.28	86.90
7	40480	JACKSON	51	8.5	800	1800	32.28	90.20
8	40480	JOHNSONVILLE	20	12.4	800	1800	36.02	87.99
9	40480	LHL	20	6.2	800	1800	36.79	88.07
10	40480	OWENSHORU	02	23.2	800	1800	37.77	87.17
11	40480	PARADISE	04	16.0	800	1800	36.76	88.07
12	40480	SHAWNEE	13	13.3	800	1800	37.15	88.77
13	40480	WATTSBAR	13	10.6	800	1800	35.60	84.79
14	40480	WIDOWSCREEK	144	4.3	800	1800	34.87	85.76

DATE=40580

UNS	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOX
15	40580	ALLEN	47	9.4	0	2400	35.07	90.13
16	40580	CUMHENT	31	8.4	0	2400	34.74	87.84
17	40580	CUMHENTLAND	24	8.7	0	2400	34.38	87.64
18	40580	GALLATIN	34	9.2	0	2400	34.33	86.40
19	40580	GILESCOUNTY	38	10.2	0	2400	35.28	86.90
20	40580	JACKSON	60	7.0	0	2400	32.28	90.20
21	40580	JOHNSONVILLE	34	9.0	0	2400	36.02	87.99
22	40580	LHL	22	4.4	0	2400	36.79	88.07
23	40580	PARADISE	39	11.3	0	2400	37.27	88.09
24	40580	SHAWNEE	32	11.0	0	2400	37.15	88.77
25	40580	WATTSBAR	20	8.4	0	2400	35.60	84.79
26	40580	WIDOWSCREEK	28	4.3	0	2400	34.87	85.76

DATE=41580

UNS	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOX
27	41580	ALLEN	36	9.0	0	2400	35.07	90.13
28	41580	ASHLAND	0	13.1	0	2400	38.47	82.67
29	41580	CUMHENT	32	7.0	0	2400	34.74	87.84
30	41580	CUMHENTLAND	14	7.0	0	2400	34.38	87.64
31	41580	FRANKFORT	0	13.4	0	2400	34.18	84.92
32	41580	GALLATIN	31	10.5	0	2400	34.33	86.40
33	41580	GILESCOUNTY	25	7.0	0	2400	35.28	86.90
34	41580	JOHNSONVILLE	37	13.5	0	2400	36.02	87.99
35	41580	OWENSHORU	0	14.4	0	2400	37.77	87.17
36	41580	PARADISE	36	10.5	0	2400	37.27	88.09
37	41580	SHAWNEE	23	10.0	0	2400	37.15	88.77
38	41580	WATTSBAR	14	7.0	0	2400	35.60	84.79
39	41580	WIDOWSCREEK	25	7.6	0	2400	34.87	85.76

BEST DOCUMENT AVAILABLE

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1980 MI-VOL DATA

DATE=41600

Obs	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
40	41000	ALLEN	81	11.7	800	2400	35.07	90.13
41	41000	ASHLAND	30	6.7	800	2400	36.47	82.67
42	41000	COLBERT	39	14.4	800	2400	34.74	87.84
43	41000	CUMBERLAND	21	6.3	800	2400	36.38	87.64
44	41000	FRANKFORT	47	11.9	730	2400	38.18	84.92
45	41000	GALLATIN	23	10.4	800	2400	36.33	86.40
46	41000	GILESCOUNTY	31	10.9	800	2400	35.28	86.90
47	41000	JACKSON	56	8.1	800	2400	32.28	90.20
48	41000	JOHNSONVILLE	30	9.5	800	2400	36.02	87.99
49	41000	LHL	24	9.5	800	2400	36.79	88.07
50	41000	OWENSROBU	50	10.4	0	2400	37.77	87.17
51	41000	OXFORD	50	6.4	800	2400	34.37	89.52
52	41000	PARADISE	40	8.8	800	2400	37.27	86.99
53	41000	SHAWNEE	45	9.0	800	2400	37.15	88.77
54	41000	WATTSBAR	14	6.8	800	2400	35.60	84.79
55	41000	WIDOWSCREEK	22	9.0	800	2400	34.87	85.76

DATE=41700

Obs	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
56	41700	ALLEN	72	14.2	800	2400	35.07	90.13
57	41700	ASHLAND	150	25.5	800	2400	36.47	82.67
58	41700	COLBERT	64	12.8	800	2400	34.74	87.84
59	41700	CUMBERLAND	33	7.1	800	2400	36.38	87.64
60	41700	FRANKFORT	127	11.0	800	2400	38.18	84.92
61	41700	GALLATIN	42	7.5	800	2400	36.33	86.40
62	41700	GILESCOUNTY	52	9.1	800	2400	35.28	86.90
63	41700	JACKSON	75	13.4	800	2400	32.28	90.20
64	41700	JOHNSONVILLE	54	10.5	800	2400	36.02	87.99
65	41700	LHL	44	9.3	800	2400	36.79	88.07
66	41700	OWENSROBU	56	12.2	800	2400	37.77	87.17
67	41700	OXFORD	55	8.3	800	2400	34.37	89.52
68	41700	PARADISE	28	8.9	800	2400	37.27	86.99
69	41700	SHAWNEE	46	9.9	800	2400	37.15	88.77
70	41700	WATTSBAR	41	8.7	800	2400	35.60	84.79
71	41700	WIDOWSCREEK	44	6.2	800	2400	34.87	85.76

DATE=42200

Obs	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
72	42200	ALLEN	138	21.4	1000	2000	35.07	90.13
73	42200	COLBERT	108	22.6	1000	2000	34.74	87.84
74	42200	CUMBERLAND	89	12.2	1000	2000	36.38	87.64
75	42200	GALLATIN	98	13.6	1000	2000	36.33	86.40
76	42200	GILESCOUNTY	71	10.9	1000	2000	35.28	86.90
77	42200	JACKSON	98	15.6	1000	2000	32.28	90.20
78	42200	JOHNSONVILLE	96	17.4	1000	2000	36.02	87.99
79	42200	LHL	118	14.2	1000	2000	36.79	88.07
80	42200	OXFORD	88	13.1	1000	2000	34.37	89.52

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1980 MI-VOL DATA

DATE=42280

OBS	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
81	42280	PARADISE	89	15.1	1000	2000	37.27	86.99
82	42280	SHAWNEE	112	18.7	1000	2000	37.15	88.77
83	42280	WATTSHAR	84	9.0	1000	2000	35.60	84.79
84	42280	WIDOWSCREEK	259	11.6	1000	2000	34.87	85.76

DATE=42380

OBS	DATE	SITE	TSP	SO4	STIME	ETIME	LAT	LOH
85	42380	ALLEN	109	14.8	600	2400	35.07	90.13
86	42380	ASHLAND	87	12.0	600	2400	38.47	82.67
87	42380	COLBERT	88	13.1	600	2400	34.74	87.84
88	42380	CUMBERLAND	107	7.7	600	2400	36.38	87.64
89	42380	FRANKFORT	102	13.8	600	2400	38.18	84.92
90	42380	GALLATIN	120	9.9	600	2400	36.33	86.40
91	42380	GILESCOUNTY	96	10.1	600	2400	35.28	86.90
92	42380	JACKSON	92	14.1	600	2400	32.28	90.20
93	42380	JOHNSONVILLE	118	13.4	600	2400	36.02	87.99
94	42380	LUL	145	9.0	600	2400	36.79	88.07
95	42380	OXFORD	113	12.6	600	2400	34.37	89.52
96	42380	PARADISE	132	12.1	600	2400	37.27	86.99
97	42380	SHAWNEE	127	7.7	600	2400	37.15	88.77
98	42380	WATTSHAR	160	9.8	600	2400	35.60	84.79
99	42380	WIDOWSCREEK	136	.	600	2400	34.87	85.76

APPENDIX C

AVERAGE MIXED LAYER CONCENTRATIONS - 1979 AND 1980

ABBREVIATION AND UNITS FOR APPENDIX C

DATE: Date of sample, month, day, year

S_TIME: Airborne sampling start time, local hours, minutes

E_TIME: Airborne sampling end time, local hours, minutes

S_CLASS: I = sampling at inflow boundary of Tennessee Valley region,
O = sampling at outflow boundary of Tennessee Valley region,
N = Eulerian/Lagrangian sampling not otherwise classified,
U = upwind sampling near Gulf Coast, D = downwind sampling
near Gulf Coast, T = sampling while traversing to I, O, N,
U, or D sampling points

PART: Total suspended particulate mass loading, $\mu\text{g m}^{-3}$

NEPH: Nephelometer, $b_{\text{scat}}, 10^{-4} \text{ m}^{-1}$

NH₄: Ammonium particulate, $\mu\text{g m}^{-3}$

SO₄: Sulfate particulate, $\mu\text{g m}^{-3}$

SO₂: Sulfur dioxide, $\mu\text{g m}^{-3}$

OZONE: Ozone, $\mu\text{g m}^{-3}$

NO_x-NO: Total gaseous nitrogen oxides expressed as nitric oxide,
 $\mu\text{g m}^{-3}$

NO₂-NO: Nitrogen dioxide expressed as nitric oxide, $\mu\text{g m}^{-3}$

NO: Nitric oxide, $\mu\text{g m}^{-3}$

FROM_LAT: Latitude coordinate (°N) of average traverse start point

FROM_LON: Longitude coordinate (°W) of average traverse start point

TO_LAT: Latitude coordinate (°N) of average traverse end point

TO_LON: Longitude coordinate (°W) of average traverse end point

MH_M: Mixing height, m above ground level

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 AVERAGE MIXED LAYER CONCENTRATIONS

095	DATE	S_TIME	E_TIME	S_CLASS	PART	NEPH	NH4	SO4	SO2	OZONE	NOX_NO	FROM_LAT	FROM_LON	TO_LAT	TO_LON	MH_M
1	101779	1600	1800	I	.	.	2.7	12.2	6	84	.	34.77	88.12	34.63	87.33	1709
2	102179	958	1029	I	123	.	1.2	5.8	17	53	6	34.55	87.05	34.60	88.48	610
3	102179	1506	1650	O	190	.	1.3	4.8	15	72	5	37.10	86.24	37.77	87.95	1524
4	102779	1146	1412	U	84	0.4350	0.9	2.9	3	98	5	29.00	90.00	29.50	92.00	1372
5	102779	1651	1804	O	180	1.2205	2.0	4.7	1	160	10	30.99	90.79	31.00	92.00	1372
6	110479	1846	2039	I	38	0.5898	1.5	5.7	11	99	5	35.00	88.00	33.50	89.00	1410
7	110579	637	751	O	76	0.6436	1.6	6.5	26	100	8	36.50	87.50	36.50	89.50	1524
8	110579	1343	1554	I	83	0.7673	2.2	6.3	16	116	9	34.39	88.49	34.39	86.47	1524
9	110579	933	1026	O	183	0.8405	1.9	.	9	51	8	37.12	86.36	37.44	87.46	1463

BEST DOCUMENT AVAILABLE

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1980 AVERAGE MIXED LAYER CONCENTRATIONS

Obs	DATE	S_TIME	E_TIME	S_CLASS	PART	NEPH	NH4	SO4	SO2	OZONE	NOX_NO	NO2_NO	NO	FROM_LAT	FROM_LON	TO_LAT	TO_LON	MM_M
1	33090	1421	1654	I	31	0.50249	0.5	2.4	2	71	4	2	1	33.84	87.72	34.87	89.27	3048
2	33130	947	1132	N	29	0.88460	1.0	4.3	8	57	5	3	2	34.50	87.70	36.90	87.75	915
3	40140	1014	1116	U	67	1.29640	1.8	11.1	6	89	6	4	2	31.50	87.18	31.50	88.62	1006
4	40290	945	1232	I	92	0.92213	1.5	7.2	5	111	5	3	2	35.24	88.52	35.18	86.07	1829
5	40280	1648	1815	O	199	0.92280	1.5	11.9	11	139	7	5	2	37.00	87.00	37.00	84.50	1829
6	40380	118	215	I	.	0.35980	0.2	4.8	0	69	3	2	2	35.01	89.23	35.90	88.14	1829
7	40440	2038	2134	I	55	0.68960	0.7	2.4	4	88	3	2	1	37.86	88.77	39.45	87.30	1829
8	40530	2350	153	T	30	0.68910	1.5	2.7	3	91	2	2	1	37.29	85.77	35.88	87.23	1677
9	40580	411	503	O	41	0.69590	.	.	.	89	2	1	1	34.25	86.20	35.50	85.50	1220
10	40580	921	1148	I	56	0.69270	0.9	2.3	17	92	6	4	2	36.50	89.57	37.92	88.23	1524
11	40590	1436	1727	T	52	0.65430	0.8	2.9	16	105	.	.	.	36.72	86.08	35.00	88.17	1677
12	40580	1959	2236	O	87	0.71080	2.0	6.7	10	100	5	4	1	34.67	87.33	35.75	85.13	1372
13	41580	1129	1401	I	110	0.76660	1.0	3.0	2	106	4	2	2	35.64	91.18	37.23	89.57	1829
14	41540	1959	2218	O	79	0.81770	1.4	4.6	5	100	5	3	1	34.75	87.61	36.35	84.17	3048
15	41640	942	1132	I	48	0.67410	1.1	3.5	14	105	.	.	.	37.82	88.55	37.03	86.07	1067
16	41740	643	910	O	42	0.57250	0.7	3.9	7	112	3	2	2	34.73	87.82	34.95	85.71	1220
17	41780	1438	1523	T	147	1.00200	1.1	3.7	10	138	8	6	2	35.82	89.42	36.08	87.38	1677
18	41980	1411	1620	U	135	1.07580	1.4	10.0	6	143	6	4	2	30.82	91.75	31.11	92.35	1799
19	41990	1749	2018	O	61	1.24670	1.5	7.7	4	141	6	4	1	29.57	92.47	29.57	90.83	1372
20	42080	952	1156	U	112	1.38720	2.4	10.1	9	152	7	6	2	30.58	92.50	29.37	90.63	1738
21	42080	1515	1803	O	110	1.30920	2.6	11.5	6	164	7	5	1	29.88	92.53	29.17	90.88	2591
22	42180	1016	1247	N	107	1.30100	2.0	10.7	6	153	8	6	1	29.60	92.33	29.61	92.34	2134
23	42180	1438	1630	N	168	1.32800	2.6	12.3	5	162	6	5	1	29.60	92.33	29.61	92.34	2134
24	42180	1836	2036	N	100	0.76190	0.8	5.4	5	108	3	2	1	30.42	91.69	34.75	87.61	2530
25	42280	850	1156	O	155	0.94750	0.7	10.8	7	116	5	4	1	35.07	89.20	33.42	87.03	3048
26	42380	711	917	I	162	1.23590	0.7	12.2	3	146	5	4	1	35.00	90.51	36.57	90.51	1585
27	42380	1112	1324	T	226	1.30250	0.7	14.5	7	146	7	6	1	34.92	89.05	37.12	87.83	3048
28	42380	1602	1805	O	281	1.18030	1.1	11.9	9	160	6	5	1	34.93	85.80	37.28	85.80	3048

APPENDIX D

AVERAGE FLUX DATA - 1979 AND 1980

ABBREVIATIONS AND UNITS FOR APPENDIX D

DATE: Date of sample, month, day, year

S_TIME: Airborne sampling start time, local hours, minutes

E_TIME: Airborne sampling end time, local hours, minutes

S_CLASS: I = sampling at inflow boundary of Tennessee Valley region,
O = sampling at outflow boundary of Tennessee Valley region,
N = Eulerian/Lagrangian sampling not otherwise classified,
U = upwind sampling near Gulf Coast,
D = downwind sampling near Gulf Coast,
T = sampling while traversing to I, O, N, U, or D sampling
points

PART: Total suspended particulate mass loading, $\mu\text{g m}^{-2}\text{s}^{-1}$

NH₄: Ammonium particulate, $\mu\text{g m}^{-2}\text{s}^{-1}$

SO₄: Sulfate particulate, $\mu\text{g m}^{-2}\text{s}^{-1}$

SO₂: Sulfur dioxide, $\mu\text{g m}^{-2}\text{s}^{-1}$

OZONE: Ozone, $\mu\text{g m}^{-2}\text{s}^{-1}$

NO_x NO: Total gaseous nitrogen oxides expressed as nitric oxide,
 $\mu\text{g m}^{-2}\text{s}^{-1}$

NO₂ NO: Nitrogen dioxide expressed as nitric oxide, $\mu\text{g m}^{-2}\text{s}^{-1}$

NO: Nitric oxide, $\mu\text{g m}^{-2}\text{s}^{-1}$

FROM_LAT: Latitude coordinate (°N) of average traverse start point

FROM_LON: Longitude coordinate (°W) of average traverse start point

TO_LAT: Latitude coordinate (°N) of average traverse end point

TO_LON: Longitude coordinate (°W) of average traverse end point

MH_M: Mixing height, m above ground level

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TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1979 FLUX DATA

OBS	DATE	S_TIME	E_TIME	S_CLASS	PART	NH4	SO4	SO2	OZONE	NOX_NO	FROM_LAT	FROM_LON	TO_LAT	TO_LON	MH_M
1	101779	1600	1900	I	.	6.7	30.4	15	209	.	34.77	88.12	34.63	87.33	1709
2	102179	958	1029	I	246	2.3	10.2	27	152	38.4	34.55	87.05	34.60	88.48	610
3	102179	1506	1650	O	1488	10.2	37.6	115	564	306.7	37.10	86.24	37.77	87.95	1524
4	102779	1146	1412	U	856	9.2	29.6	30	999	540.4	29.00	90.00	29.50	92.00	1372
5	102779	1651	1804	D	2092	23.2	54.6	16	1860	1337.6	30.99	90.79	31.00	92.00	1372
6	110479	1846	2039	I	52	2.1	7.8	14	136	9.4	35.00	88.00	33.50	89.00	1410
7	110579	637	751	O	370	7.8	31.6	126	487	192.0	36.50	87.50	36.50	89.50	1524
8	110579	1343	1554	I	272	7.2	20.7	52	381	98.0	34.39	88.49	34.39	86.47	1524
9	110679	933	1026	O	1599	16.6	.	80	446	641.3	37.12	86.36	37.44	87.46	1463

BEST DOCUMENT AVAILABLE

TENNESSEE REGIONAL ATMOSPHERIC TRANSPORT STUDY 1980 FLUX DATA

OBS	DATE	S_TIME	E_TIME	S_CLASS	PART	NH4	SO4	SO2	OZONE	NOX_NO	NO2_NO	NO	FROM_LAT	FROM_LON	TO_LAT	TO_LON	MH_M
1	33080	1421	1654	I	633	10.2	49.0	47	1450	76	49	27	33.84	87.72	34.87	89.27	3048
2	33180	947	1132	N	183	6.3	27.2	47	361	32	22	11	34.50	87.70	36.90	87.75	915
3	40180	1014	1116	U	104	2.8	17.2	9	138	9	6	3	31.50	87.18	31.50	88.62	1006
4	40280	945	1232	I	376	6.1	29.4	20	454	21	13	8	35.24	88.52	35.18	86.07	1829
5	40280	1448	1915	O	755	5.7	45.2	40	527	25	17	8	37.00	87.00	37.00	84.50	1829
6	40380	118	215	I	.	2.4	57.4	0	826	38	18	20	35.01	89.23	35.90	88.14	1829
7	40480	2038	2134	I	733	9.3	32.0	53	1173	37	23	15	37.86	88.77	39.45	87.30	1829
8	40580	2350	153	T	337	16.9	30.3	29	1023	26	17	8	37.29	85.77	35.88	87.23	1677
9	40580	411	503	O	255	.	.	.	554	9	6	4	34.25	86.20	35.50	85.50	1220
10	40580	921	1148	I	198	3.0	8.4	60	347	21	13	7	36.50	89.57	37.92	88.23	1524
11	40580	1436	1727	T	218	3.4	12.2	66	440	.	.	.	36.72	86.08	35.00	88.17	1677
12	40580	1959	2236	O	89	2.0	6.8	10	102	5	4	1	34.67	87.33	35.75	85.13	1372
13	41580	1129	1401	I	1100	8.9	32.9	24	1252	39	20	18	35.64	91.18	37.23	89.57	1829
14	41580	1959	2218	O	1639	29.1	95.5	112	2075	93	66	27	34.75	87.61	36.35	84.17	3048
15	41680	942	1132	I	133	3.1	9.7	39	292	.	.	.	37.82	88.55	37.03	86.07	1067
16	41780	643	910	O	85	1.1	6.0	9	211	6	3	3	34.73	87.82	34.95	85.71	1220
17	41780	1438	1523	T	983	7.4	24.8	67	923	56	43	13	35.82	89.42	36.08	87.38	1677
18	41980	1411	1620	U	1085	11.3	80.4	48	1149	45	32	13	30.82	91.75	31.11	92.35	1799
19	41980	1749	2018	O	321	7.9	40.5	21	741	29	22	7	29.57	92.47	29.57	90.83	1372
20	42080	952	1156	U	306	5.7	24.6	22	436	19	13	2	30.58	92.50	29.37	90.63	1738
21	42080	1515	1803	D	1152	27.2	120	65	1718	69	56	15	29.88	92.53	29.17	90.88	2591
22	42180	1016	1247	N	158	3.0	15.8	8	276	11	9	2	29.60	92.33	29.61	92.34	2134
23	42180	1438	1630	N	496	7.7	36.3	15	478	17	14	3	29.60	92.33	29.61	92.34	2134
24	42180	1836	2036	N	1009	8.1	54.5	50	1090	32	18	14	30.42	91.69	34.75	87.61	2530
25	42280	850	1156	O	905	4.1	63.0	43	677	29	20	8	35.07	89.20	33.42	87.03	3048
26	42380	711	917	I	726	3.3	46.6	17	793	25	17	2	35.00	90.51	36.57	90.51	1585
27	42380	1112	1324	T	2931	9.1	188	91	1894	88	71	17	34.92	89.05	37.12	87.83	3048
28	42380	1602	1805	O	4419	17.3	187	135	2516	93	75	17	34.93	85.80	37.28	85.80	3048

APPENDIX E

SYNOPTIC METEOROLOGICAL SUMMARIES - 1979 AND 1980

APPENDIX E. SYNOPTIC METEOROLOGICAL SUMMARIES

The following summaries describe synoptic weather conditions on days when regional airborne measurements were made. The field intensive area was divided in two to better differentiate between meteorological events influencing study activities. These two areas are shown in figure E1. Frontal locations, clouds, wind velocity, temperatures, and mixing levels are presented. Also presented are backward and forward air parcel trajectories for the middle of the mixed layer (~1000 m above mean sea level [MSL]) for each airborne sampling flight. These trajectories were obtained using data from the National Weather Service (Long et al., 1978). The large rectangular area on each trajectory map outlines the modeling area.

FALL 1979

In the southeastern United States, October and early November are characterized by late autumn weather. Increasing frontal passages and low-pressure systems originating along the Gulf Coast make inroads into the dominate Bermuda high-pressure system of late summer and early fall. These weather systems cause increased cloudiness and greater probabilities for rainfall. Air mass characteristics change frequently. Typical inversion heights and boundary layer wind speeds are less than 400 m and 4 m s^{-1} in the morning and 1500 m and 5 m s^{-1} in the afternoon. Typical daily maximum temperatures for this season average about 20°C , and daily minimum temperatures average around 6°C . Precipitation occurs on about one out of three days. High-pressure systems predominate with centers typically located north and east of the region. Modified continental polar air masses occur most frequently followed by maritime tropical air masses. Cloud cover averages around 55 percent.

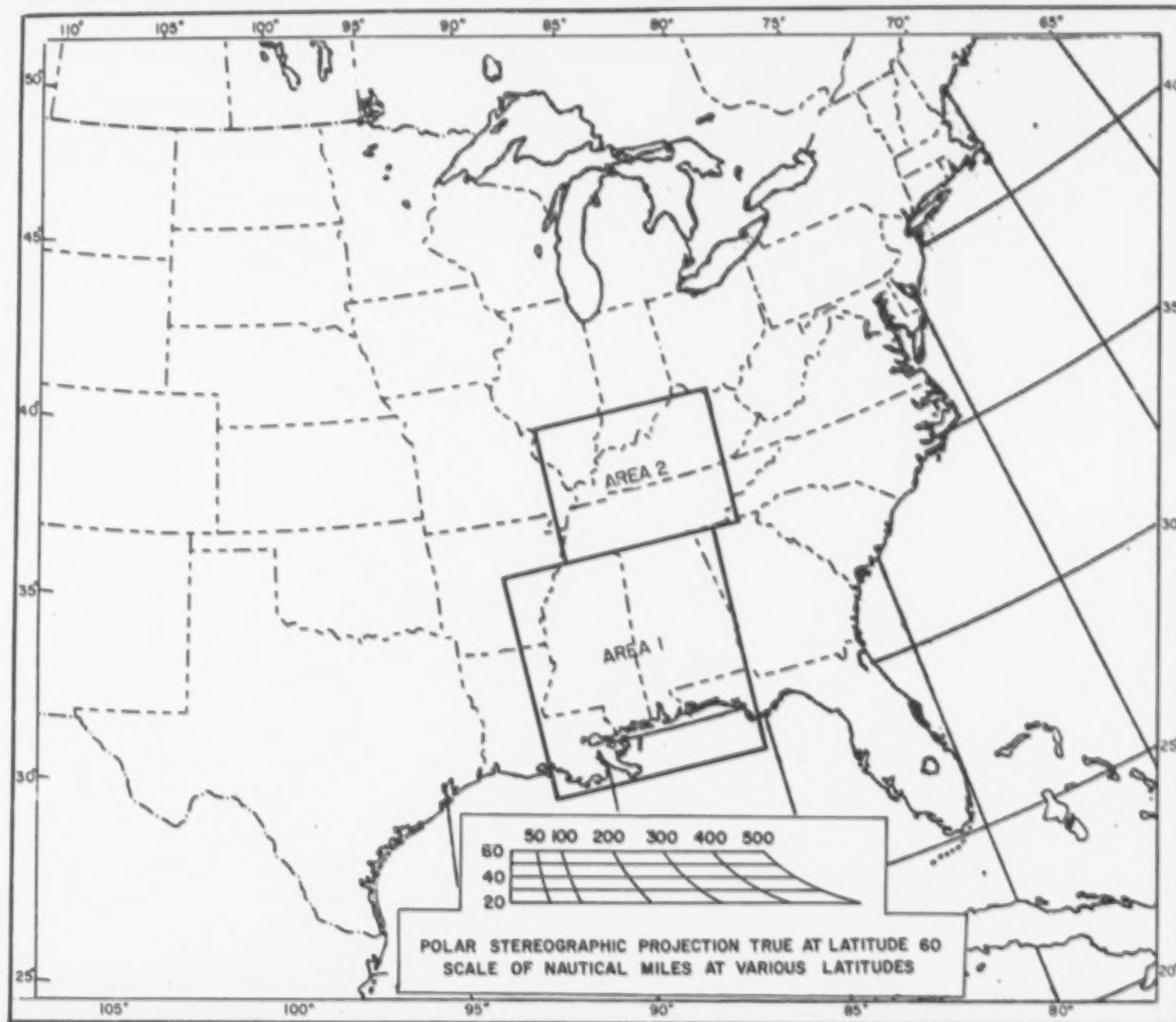


Figure E1. Field study areas.

OCTOBER 17, 1979

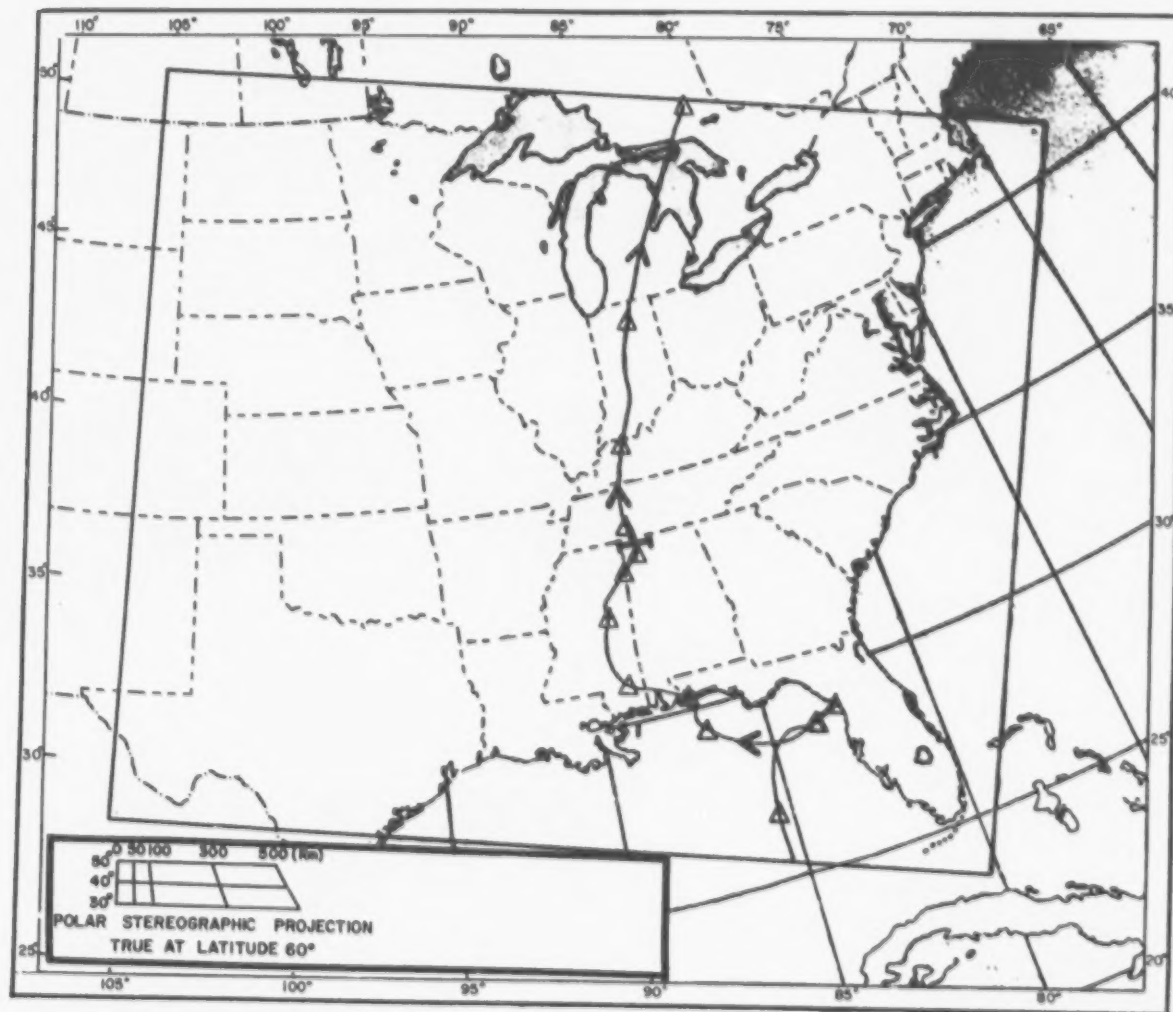
The weather pattern on this date was characterized by a weakening ridge of high pressure over study area 2. A weak cold front was located to the west of the area across north-central Illinois-Missouri. There were generally fair skies with southeasterly surface winds in the morning southwesterly winds by midday. Area-wide temperatures were warm, with highs around 25°C. Winds aloft were southerly from near surface to 1700 m above ground level (AGL), the top of the afternoon mixed layer. The top of the morning surface inversion was about 200 m AGL. Figure E2 presents the 1000 m MSL trajectory for the sampled air parcel.

OCTOBER 21, 1979

The synoptic pattern on this date continued to be influenced by a large ridge of high pressure. This ridge had characterized the synoptic pattern for the past week. No frontal systems were present near sampling area 2, the closest being over the Great Plains. Variable cloudiness, with bases above 1000 m AGL, and south-southwest surface winds characterized the prevailing weather conditions. Area-wide temperatures ranged from morning lows around 19°C to afternoon highs around 30°C.

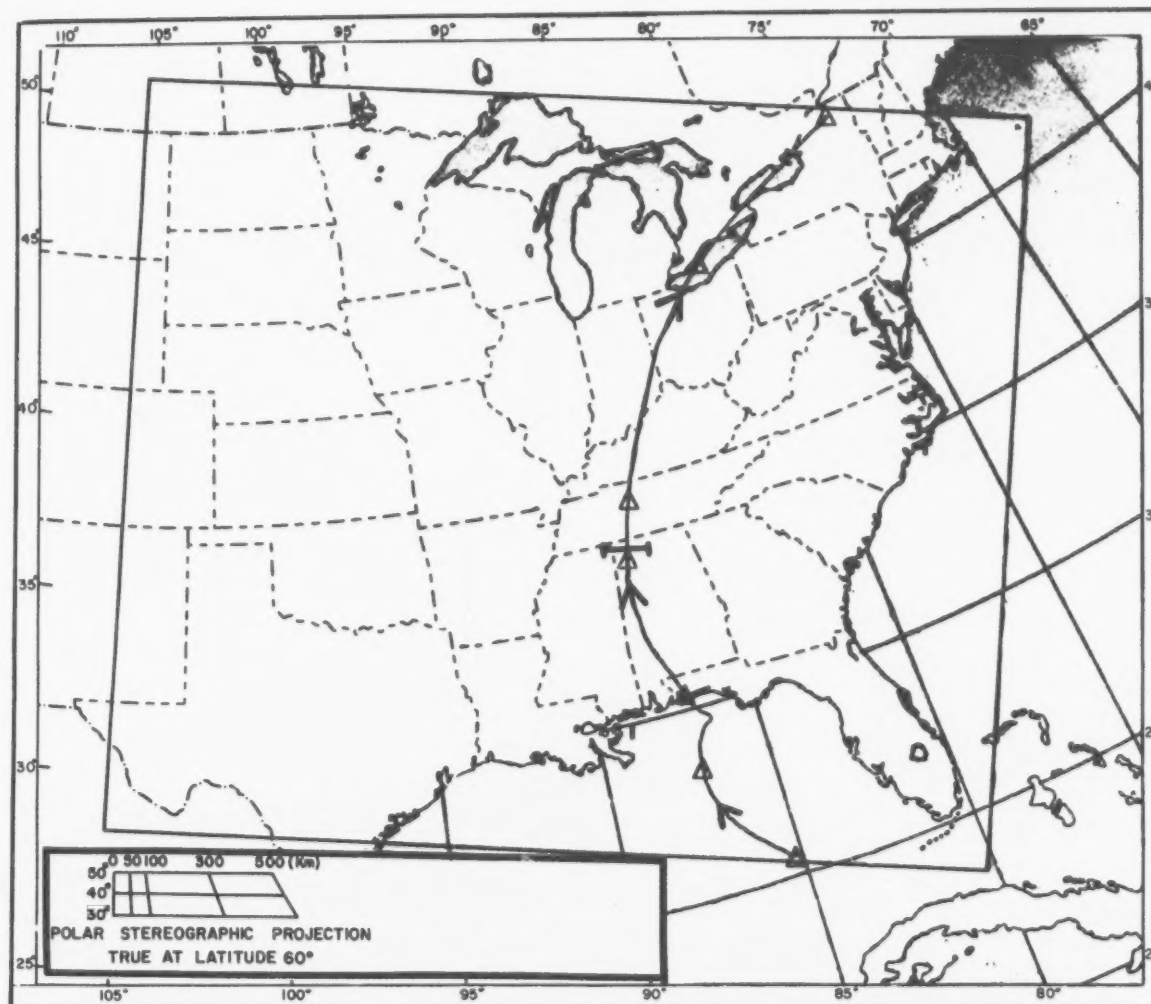
The mixing height in the morning averaged about 600 m AGL rising to about 1500 m AGL by midday. Average wind speeds in the mixing layer were 9-11 m s⁻¹ in the morning and 10-12 m s⁻¹ during the afternoon. Average wind directions through the mixing layer were southwesterly. Figures E3 and E4 show the 1000 m MSL air parcel trajectories.

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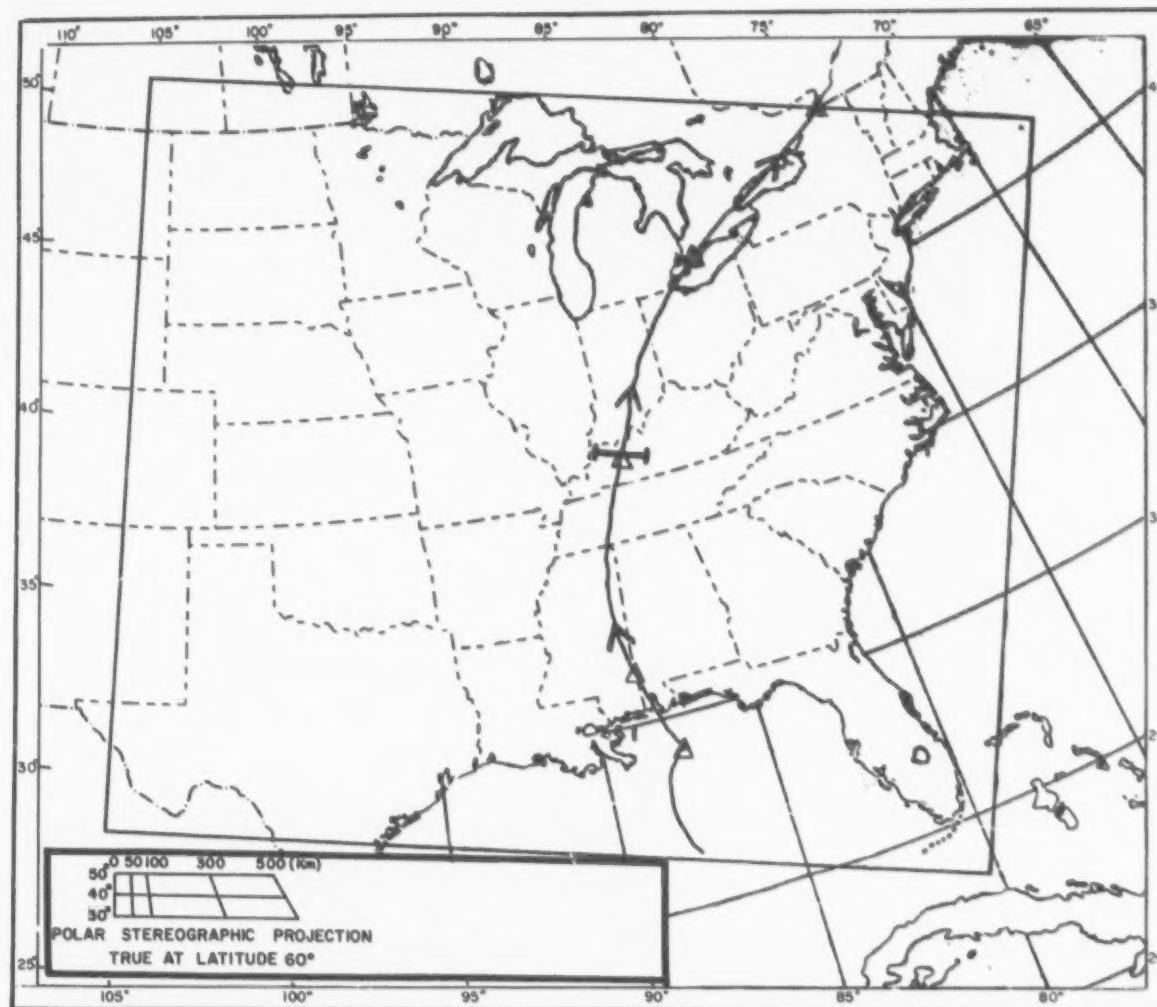


1,000 m MSL trajectory (12h intervals between triangles) 10/13/79 0100 CDT to 10/19/79 1100 CDT and aircraft sampling path (---) 10/17/79 1600-1800 CDT.

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1,000 m MSL trajectory (12h intervals between triangles) 10/19/79 2100 CDT to 10/22/79 1200 CDT and aircraft sampling path (—) 10/21/79 0958-1029 CDT.



1,000 m MSL trajectory (12h intervals between triangles) 10/20/79 0400 CDT to 10/22/79 1400 CDT and aircraft sampling path (---) 10/21/79 1506-1650 CDT.

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OCTOBER 27, 1979

The synoptic pattern over area 1 and 2 was characterized by high pressure centered over southern West Virginia. A warm frontal system across Missouri was influencing the weather along the western portion of area 2. Skies were generally clear and surface winds southwesterly in area 1. Middle and high clouds were present in area 2 associated with the warm front. Morning fog was present along the Gulf Coast. Area-wide temperatures ranged from morning lows of about 7°C in area 1 and 4°C in area 2 to average afternoon highs of about 26°C in area 1 and about 24°C in area 2. The average morning surface inversion in area 1 was about 100 m AGL; by afternoon the mixing height was about 1400 m AGL. Average wind speeds in the mixing layer (area 1) were 3-5 m s⁻¹ in the morning, increasing to 7-10 m s⁻¹ during the afternoon. Average wind direction was southwest to west-southwest. The average morning surface inversion in area 2 was about 90 m AGL; by afternoon the mixing height was about 900 m AGL. Average wind speeds in the mixing layer (area 2) were 2-3 m s⁻¹, increasing to 6-8 m s⁻¹ during the afternoon. Average wind direction was south to south-southwest. Figures E5 and E6 present the 1000 m MSL trajectories for the sampled air parcels.

NOVEMBER 4, 1979

The synoptic pattern on this day was characterized by a large high-pressure system centered over Ohio. Skies were generally clear to partly cloudy throughout the afternoon and evening. Area 2-wide

temperatures averaged about 15°C for afternoon highs. Afternoon mixing heights were about 1500 m AGL. Average wind in the mixing layer was east-northeast to east 3-4 m s⁻¹ in the afternoon becoming light and variable by evening. Figure E7 presents the 1000 m MSL air parcel trajectory.

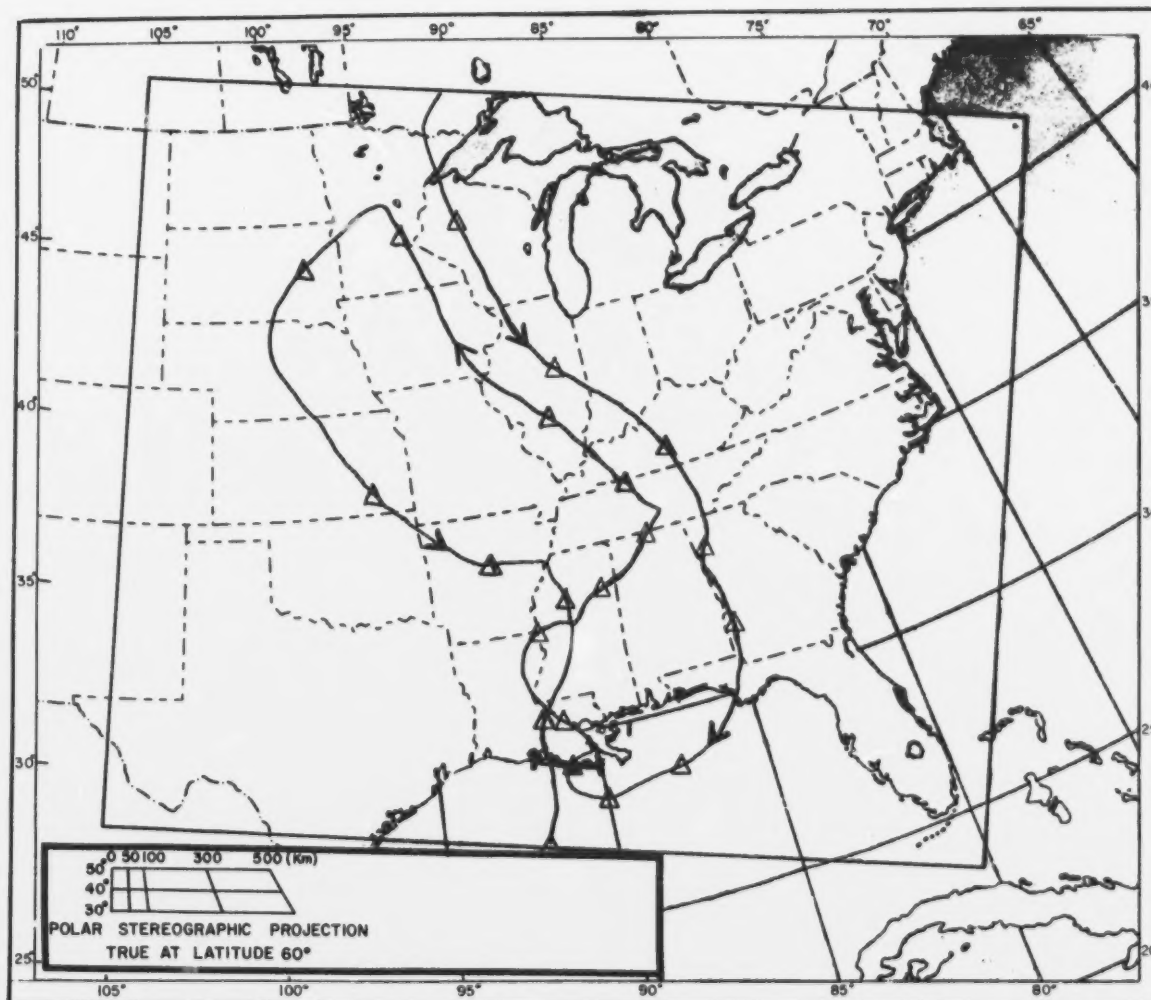
NOVEMBER 5, 1979

The synoptic pattern over study area 2 was characterized by a weakening ridge of high pressure over the area and a slow moving cold front in the central plains. The ridge moved eastward throughout the day allowing the front to reach the study area by midnight. Skies were generally cloudy; ceilings were above 1000 m AGL with spotty rain showers developing late in the day (precipitation averaged less than 0.6 cm over the area). Area-wide temperatures ranged from about 2°C for morning lows to about 18°C for afternoon highs. The average inversion height in the morning was about 80 m AGL, rising to about 1500 m during the afternoon. Average winds in the mixing layer were 2-4 m s⁻¹ in the morning, increasing to 8-10 m s⁻¹ during the afternoon. Wind direction was south-southeast, gradually shifting to southwest by evening. Figures E8 and E9 present the 1000 m MSL trajectories for the sampled air parcels.

NOVEMBER 6, 1979

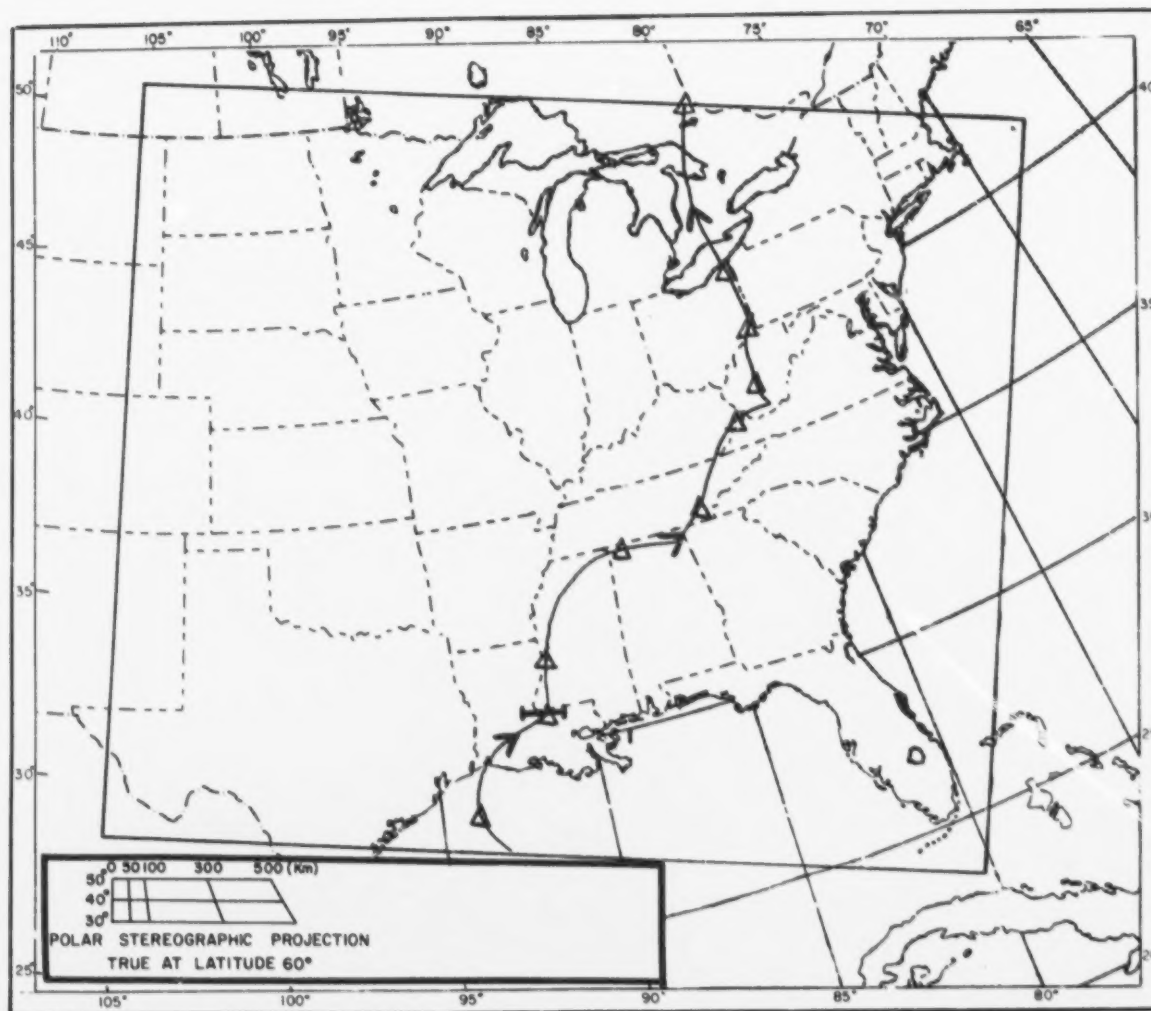
The synoptic pattern over study area 2 was characterized by a cold frontal system extending from a low-pressure center over southern Michigan, southeastward through Indiana, Illinois, and Arkansas. The

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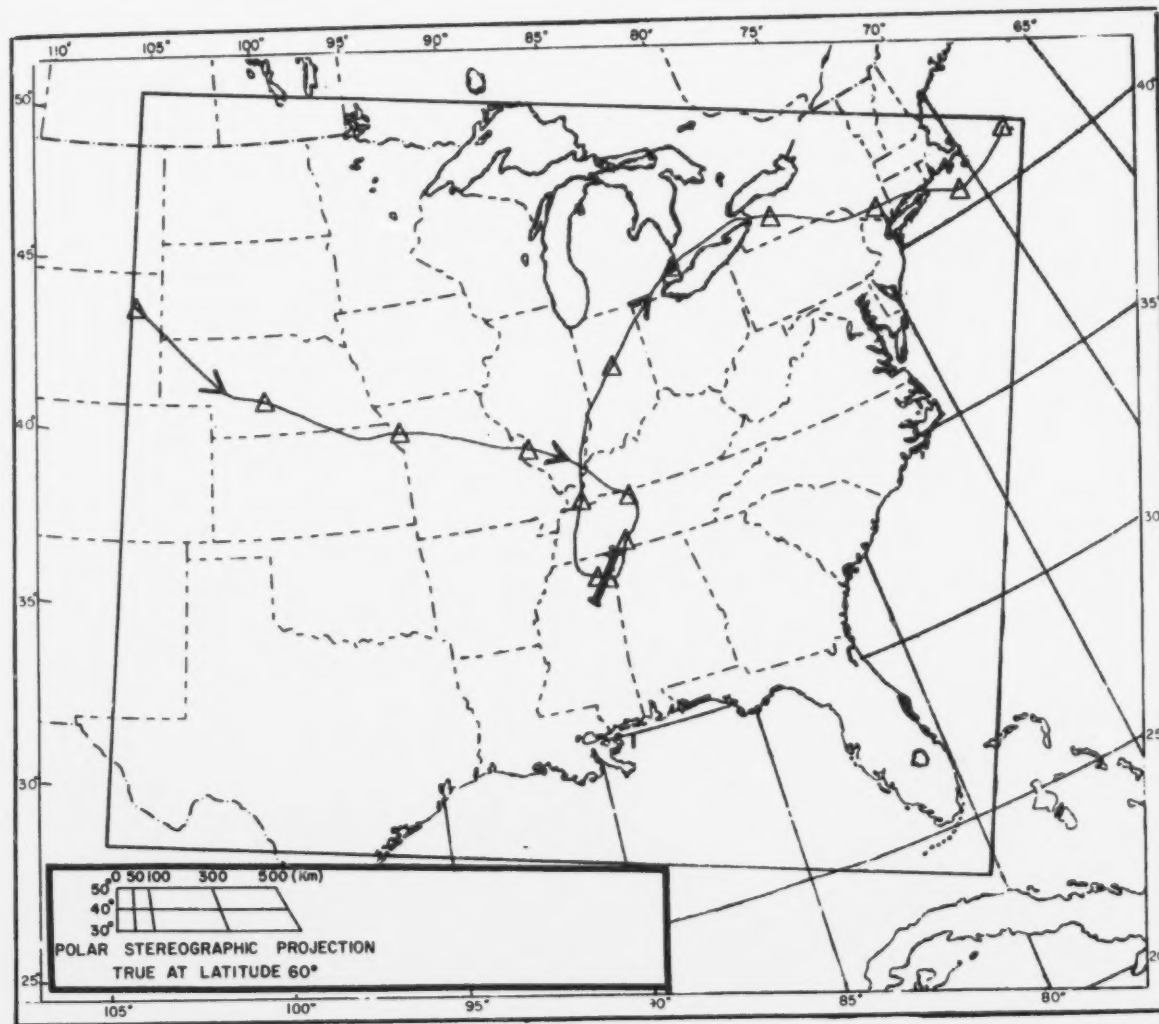
1,000 m MSL trajectory (12h intervals between triangles) 10/23/79 1400 CDT to 11/2/79 2300 CDT and aircraft sampling path (---) 10/27/79 1146-1412 CDT.

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1,000 m MSL trajectory (12h intervals between triangles) 10/26/79 2100 CDT to 11/31/79 1100 CDT and aircraft sampling path (|—|) 10/27/79 1651-1804 CDT.

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1,000 m MSL trajectory (12h intervals between triangles) 11/01/79 2100 CST to 11/08/79 1300 CST and aircraft sampling path (—○—) 11/04/79 1846-2039 CST.

front moved eastward through the study area producing overcast skies and light showers. Precipitation across the area averaged less than 0.6 cm. Area-wide temperatures averaged about 5°C for the morning lows. The average inversion height in the morning was about 50 m AGL rising to about 1400 m AGL by afternoon. Average wind in the mixing layer was 3-6 m s⁻¹ in the morning, increasing to 8-10 m s⁻¹ by afternoon. Wind direction was westerly. The 1000 m MSL air parcel trajectory is shown in figure E10.

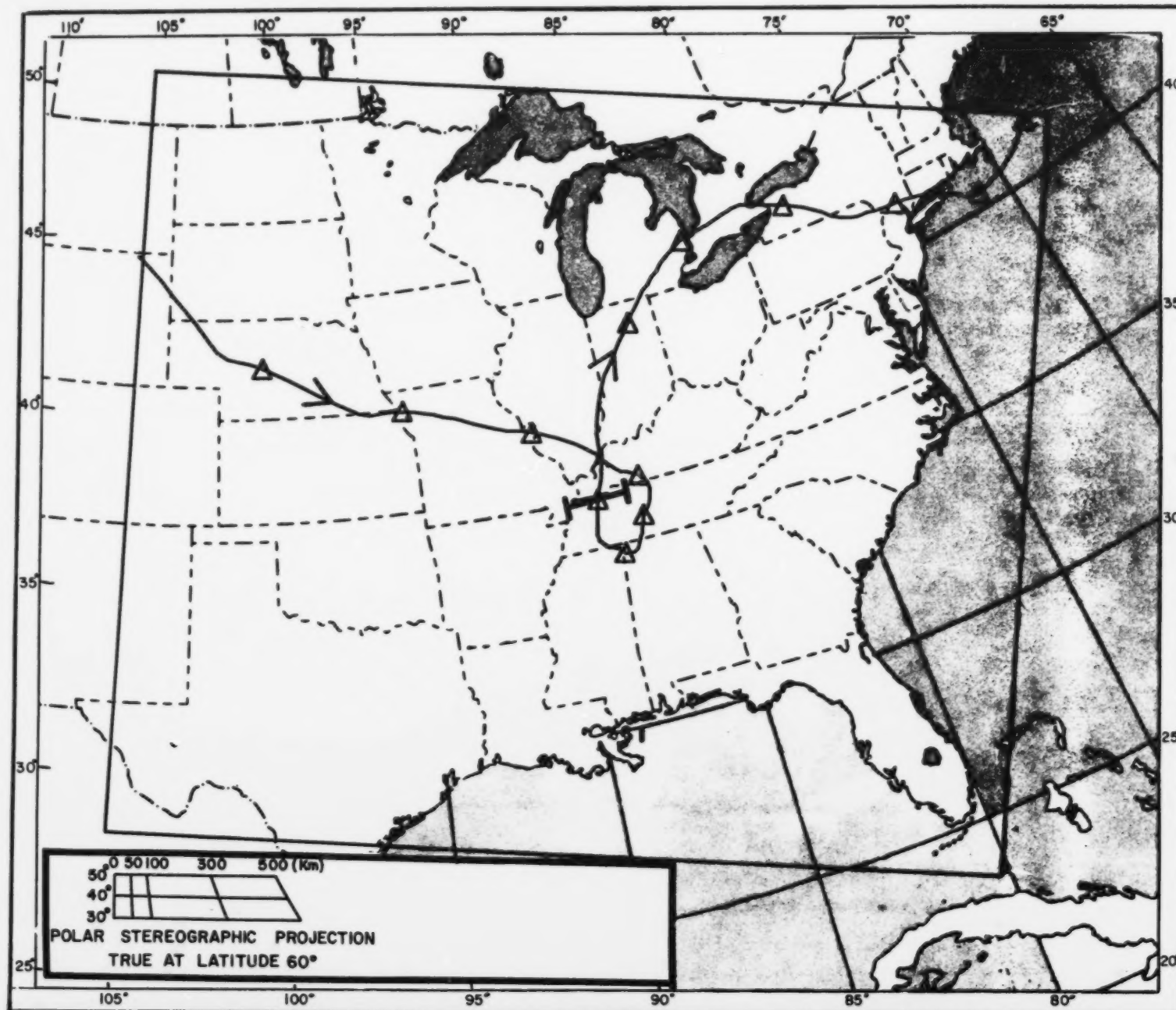
SPRING 1980

April in the southern United States is characterized by midspring weather; increasing warm air advection of moist maritime air often produces shower activity especially when fronts are present. About one out of three days has precipitation; average cloud cover is 60 percent. Typical daily high and low temperatures are 23°C and 10°C respectively. Typical inversion heights and wind speeds are about 500 m and 5 m s⁻¹ in the morning and 1700 m and 7 m s⁻¹ in the afternoon. High-pressure systems occur most frequently with the centers of these systems typically located northeast and east of Nashville. Maritime tropical and modified polar airmasses occur equally during this time of the year and account for 80 percent of all airmass types.

MARCH 30, 1980

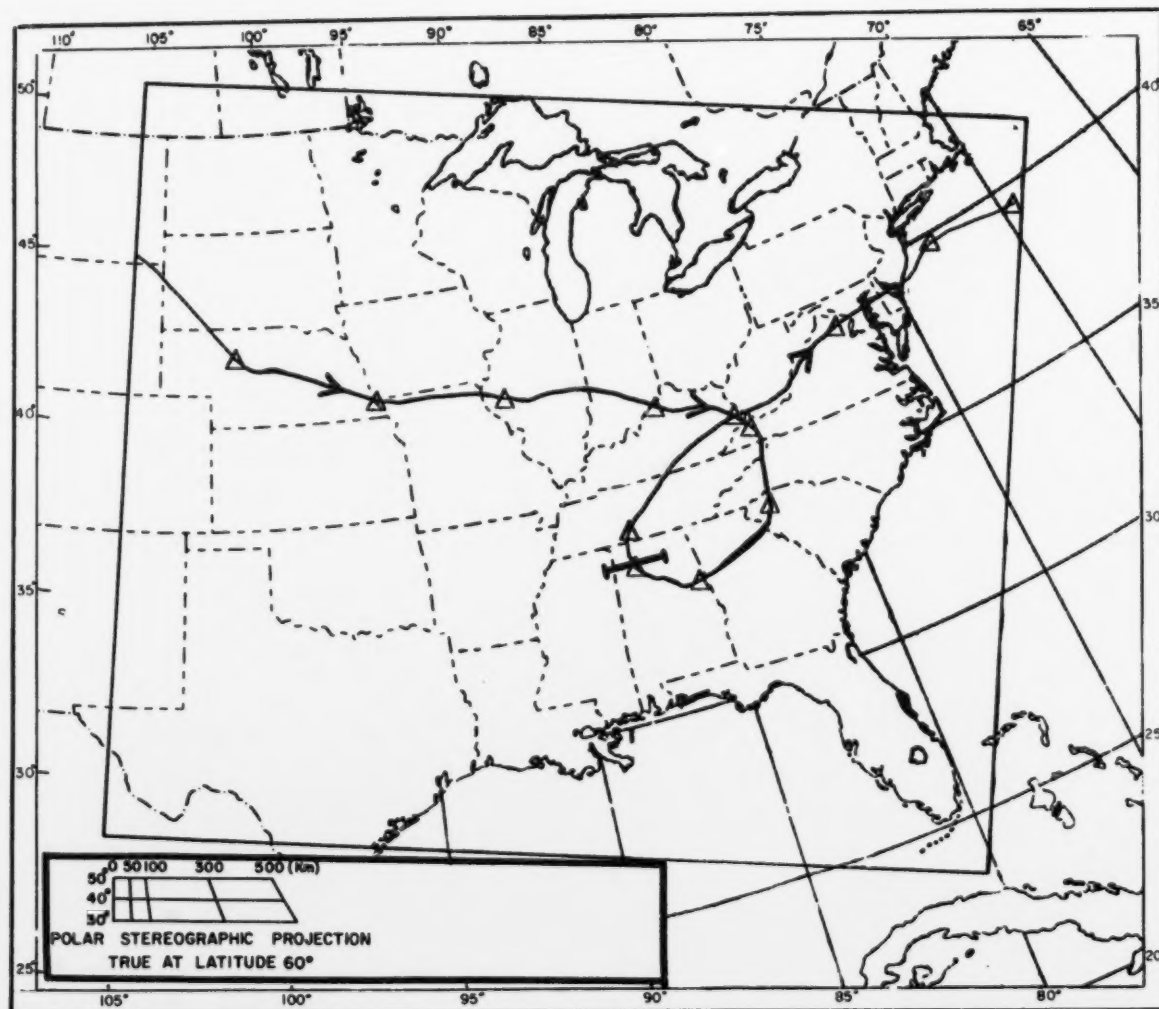
The synoptic pattern on this day was characterized by a trough of low pressure extending from southwestern Missouri to the Florida panhandle.

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1,000 m MSL trajectory (12h intervals between triangles) 11/01/79 2100 CST to 11/08/79 1200 GMT and aircraft sampling location (1, 2) 11/05/79 0600Z 0751.00M

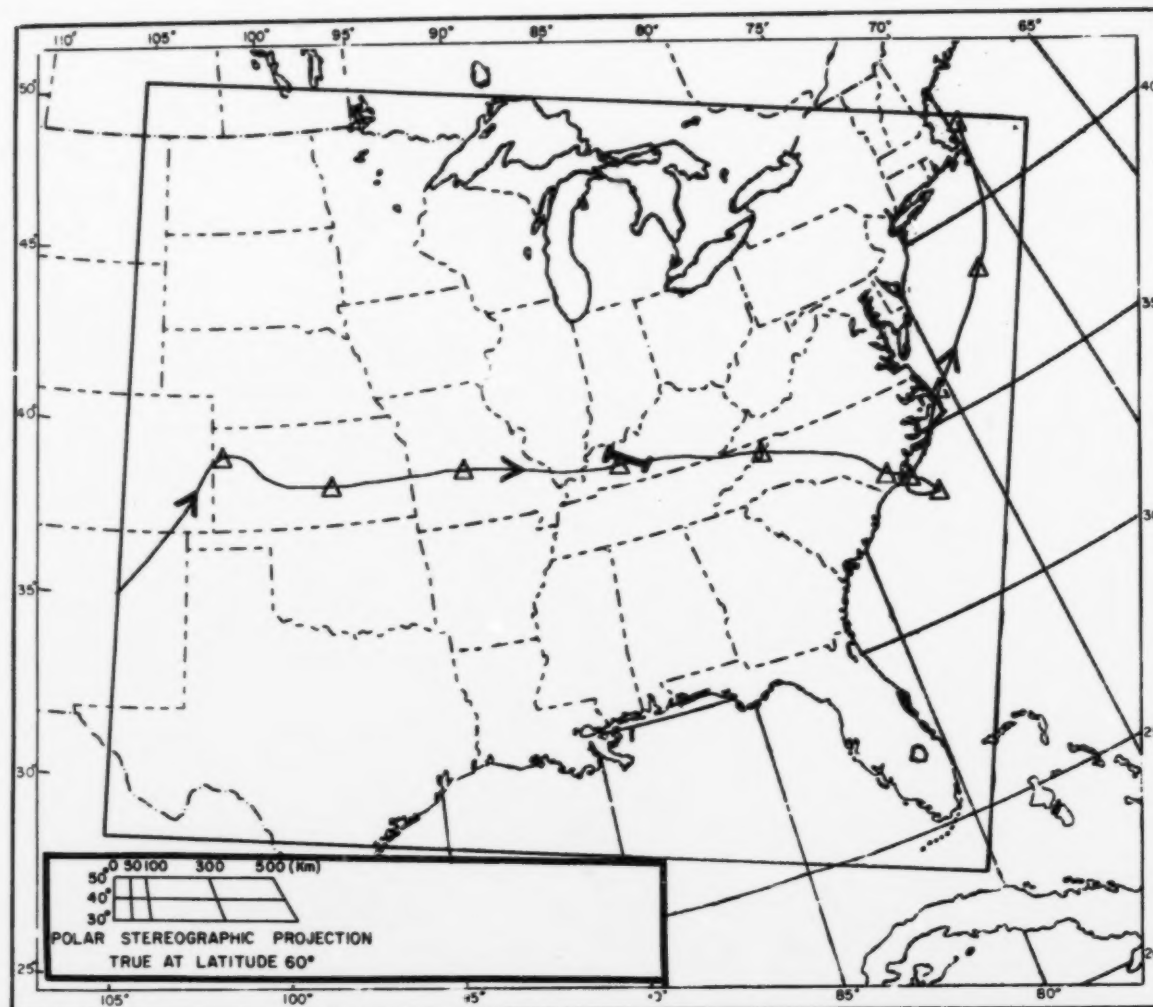
63



1,000 m MSL trajectory (12h intervals between triangles) 11/01/79 1800 CST to 11/07/79 2000 CST and aircraft sampling path (---) 11/05/79 1343-1554 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 11/04/79 1100 CST to 11/09/79 2000 CST and aircraft sampling path (|—|) 11/06/79 0933-1026 CST.

Generally overcast skies and light rain characterized the prevailing weather conditions. Precipitation averaged less than 0.6 cm over study area 2. Area-wide temperatures averaged about 15°C for the afternoon high. The average afternoon mixing height was above 3000 m AGL. Average wind in the mixing layer was west-southwest 10-12 m s⁻¹. The 1000 m MSL trajectory for the sampled air parcel is shown in figure E11.

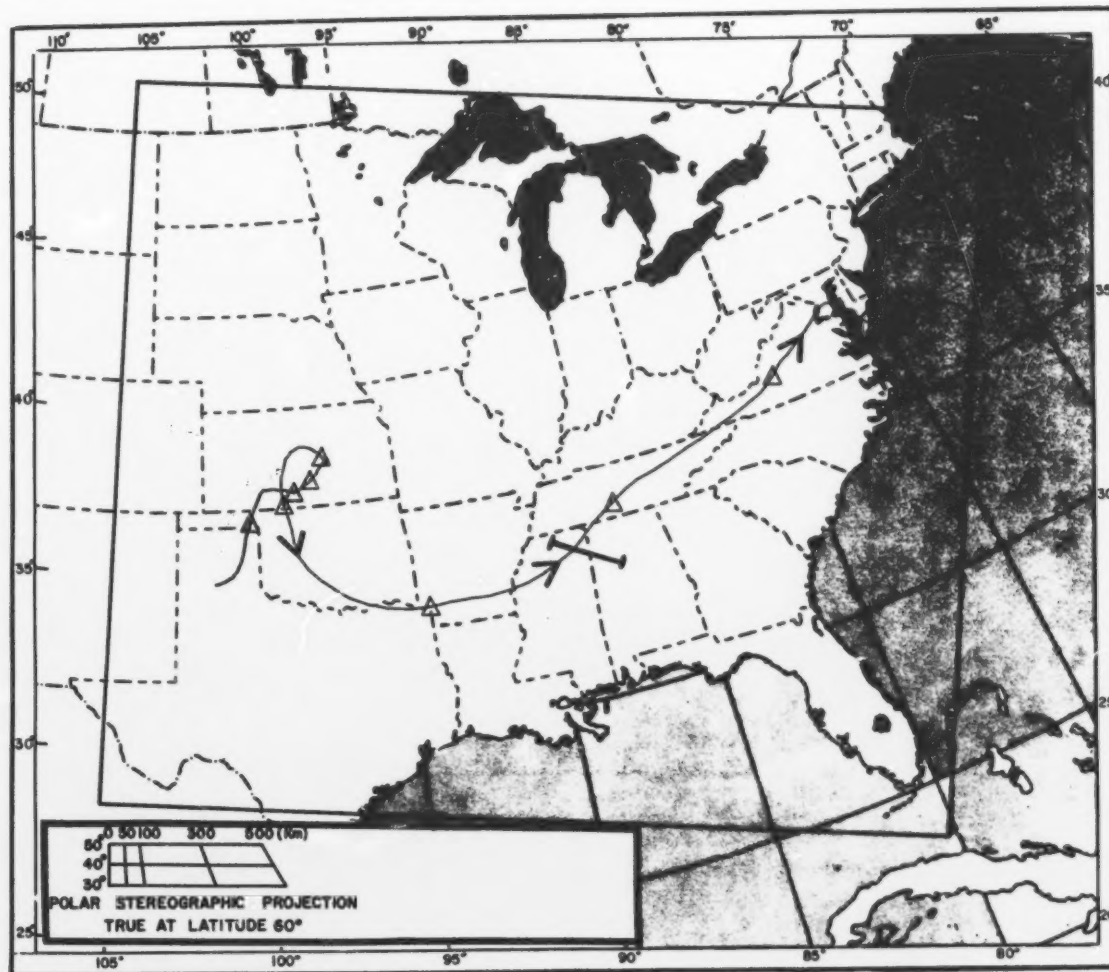
MARCH 31, 1980

The synoptic pattern on this day was characterized by post-frontal weather associated with a trough (see March 30, 1980 discussion) which had moved east of the study area by 0700 CST. Cloudy skies and scattered rain showers characterized the prevailing weather conditions over study area 2. Precipitation amounts across the area averaged between 0.6 and 1.3 cm. Average area-wide temperatures ranged from a morning low of 7°C to an afternoon high of about 10°C. Surface winds were southwest to west-southwest during the morning. The average mixing height in the morning was about 1000 m AGL rising slightly by afternoon. Average winds in the mixing layer were 11-13 m s⁻¹ throughout the morning and afternoon. Figure E12 shows the 1000 m MSL air parcel trajectory.

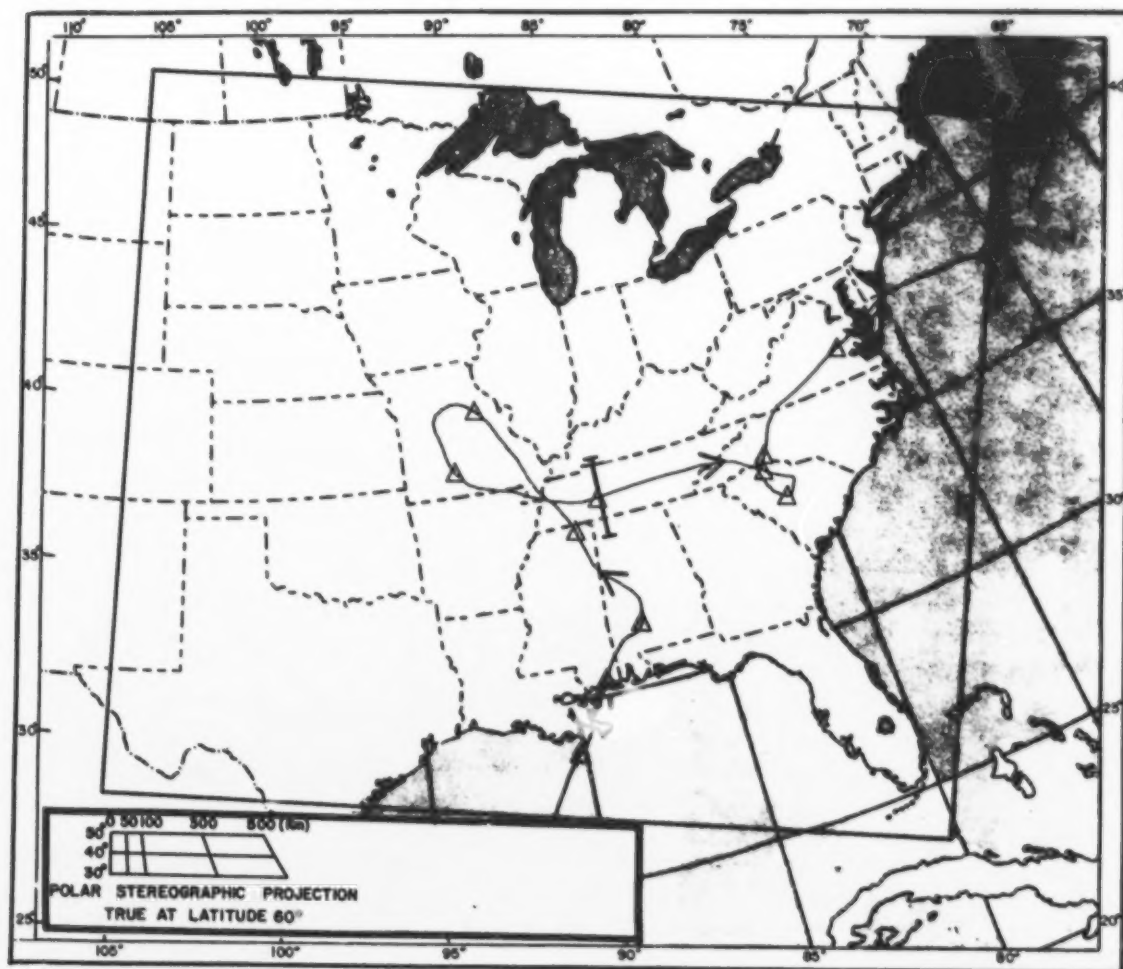
APRIL 1, 1980

The synoptic pattern on this day was characterized by high pressure centered over Kentucky. A low-pressure system was located over central Kansas with a warm front extending east-southeast across Missouri and a cold front extending southwest across Oklahoma and Texas. This frontal

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1,000 m MSL trajectory (12h intervals between triangles) 3/27/80 1800 CST to 4/01/80 0600 CST and aircraft sampling path (|—|) 3/30/80 1421-1654 CST.



1,000 m MSL trajectory (12h intervals between triangles) 3/28/80 0600 CST to 4/03/80 0200 CST and aircraft sampling path (—) 3/31/80 0947-1132 CST.

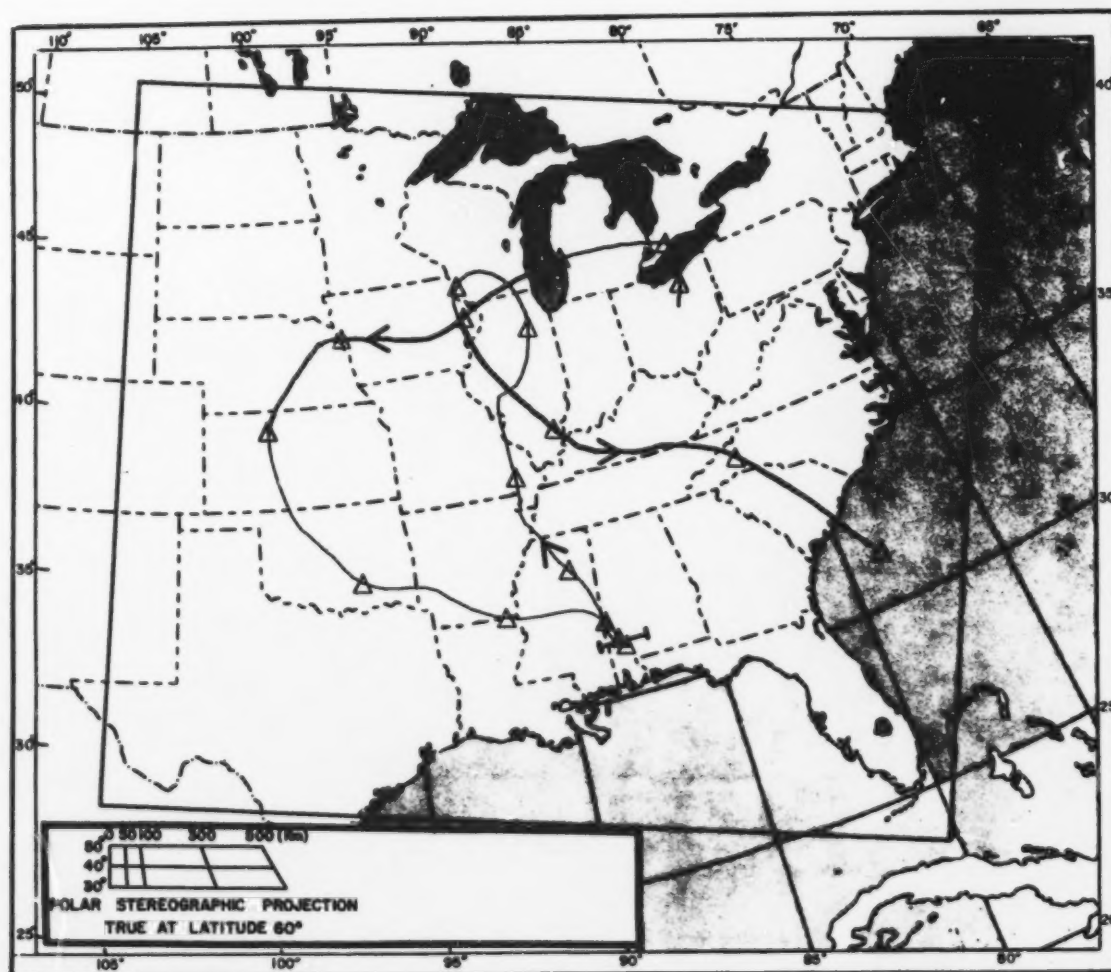
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system moved eastward and weakened throughout the day. Patchy strato-cumulus clouds (above 1000 m) and isolated rain showers (less than 0.6 cm accumulation) prevailed over study area 2, while partly cloudy skies and no precipitation prevailed over area 1. Area-wide temperatures ranged from morning lows of about 5°C to afternoon highs around 20°C in area 2. Morning lows in area 1 ranged from 4°C in the north half to 11°C in the southern half. Afternoon highs in area 1 averaged about 24°C. Surface winds were east-southeast in area 1 and west-southwest in area 2. Average inversion heights in the morning were about 140 m AGL in area 1 and about 960 m AGL in area 2 rising to about 1000 m AGL in area 1 and about 1200 m AGL in area 2 by afternoon. Average wind speeds in the mixing layer were 3-6 m s⁻¹ throughout the day. The 1000 m MSL air parcel trajectory is shown in figure E13.

APRIL 2, 1960

The synoptic pattern on this date was characterized by a frontal system extending from western Tennessee through Arkansas, southern Oklahoma and northern Texas to a low pressure system over New Mexico. This system moved northeastward throughout the day. A warm frontal system was located along the Gulf Coast. Skies were mostly cloudy in the southern portion of study area 2 and partly cloudy over the northern portion. No precipitation was observed throughout the day. Surface winds were east-southeast to southeast over the study area. Area-wide temperatures ranged from morning lows of about 5°C to afternoon highs of about 25°C. Average inversion heights in the morning were about 50 m

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1,000 m MSL trajectory (12h intervals between triangles) 3/27/80 1800 CST to 4/05/80 0900 CST and aircraft sampling path (|—|) 4/01/80 1014-1116 CST.

AGL rising to about 1800 m AGL by afternoon. Average wind speeds in the mixing layer were $2-4 \text{ m s}^{-1}$ in the morning increasing to $5-8 \text{ m s}^{-1}$ by afternoon. Figures E14 and E15 show the 1000 m MSL air parcel trajectories.

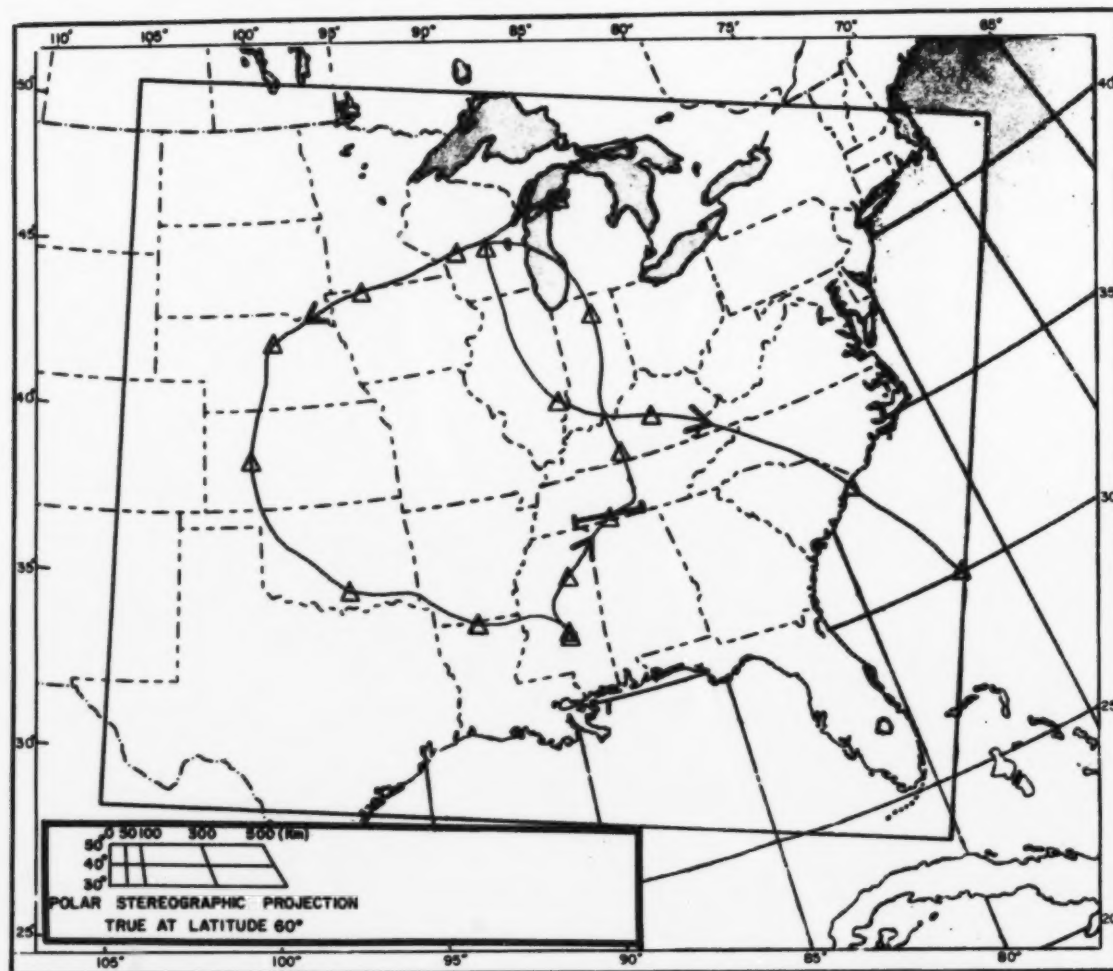
APRIL 3, 1980

The synoptic pattern on this date was characterized by a warm frontal system extending eastward across the study area from central Missouri through southern Illinois, southern Kentucky, and into Virginia. A cold front extended southward from central Missouri through Arkansas into Texas. The system moved through the Valley during the day (after the hours of sampling). Associated weather over study area 2 was characterized by overcast skies and widely scattered rain showers. A trace of precipitation was observed in the western portion of the study area. Surface winds were east-southeast to south. Area-wide morning low temperatures averaged about 9°C . The average morning mixing height was about 1800 m AGL. Average wind speeds in the mixing layer were $8-12 \text{ m s}^{-1}$. Figure E16 presents the 1000 m MSL air parcel trajectory.

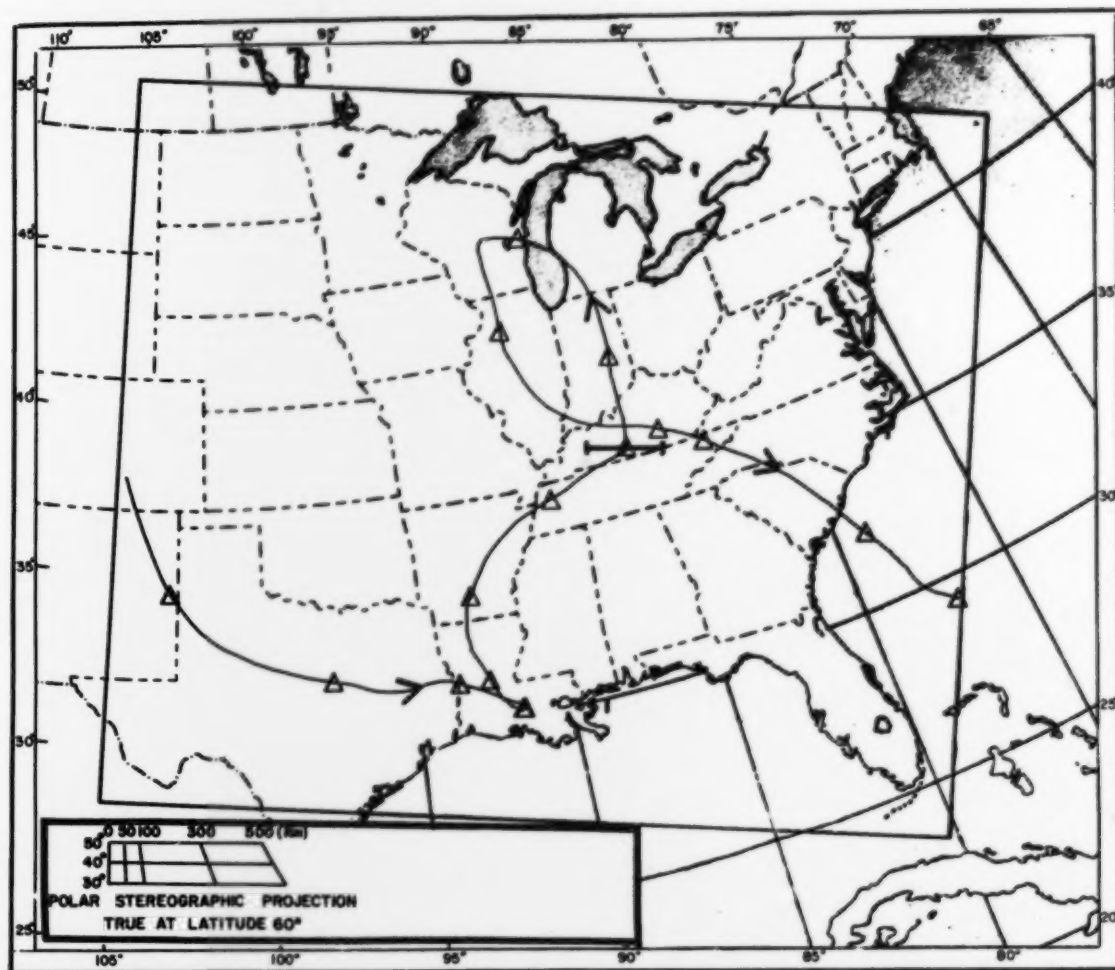
APRIL 4, 1980

A synoptic pattern on this day was characterized by a large area of high pressure moving over study area 2 behind a frontal system which passed through the area on the previous day. Skies were partly cloudy over the south and western portions of the area and cloudy over the remainder. Early morning precipitation amounts in the study area were less than 0.6 cm. Surface winds were generally west to west-northwest.

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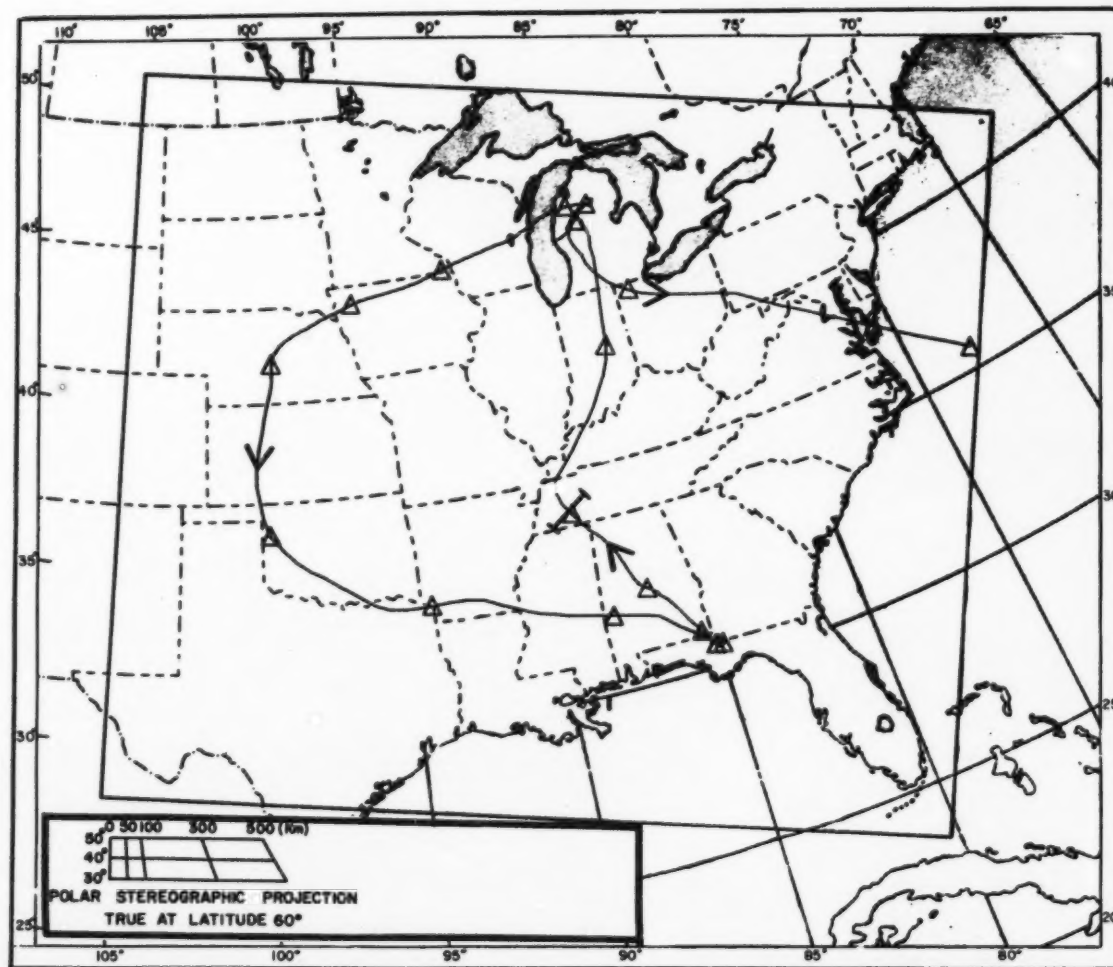


1,000 m MSL trajectory (12h intervals between triangles) 3/27/80 1800 CST to 4/05/80 1700 CST and aircraft sampling path (---) 4/02/80 0945-1232 CST.



1,000 m MSL trajectory (12h intervals between triangles) 3/30/80 0100 CST to 4/05/80 2100 CST and aircraft sampling path (|—|) 4/02/80 1648-1815 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 3/27/80 1800 CST to 4/05/80 0700 CST and aircraft sampling path (—) 4/03/80 0118-0215 CST.

Area-wide afternoon high temperatures averaged about 16°C. The average afternoon mixing height was about 1800 m AGL. Average wind speeds in the mixing layer were 10-14 m s⁻¹. The 1000 m air parcel trajectory is shown in figure E17.

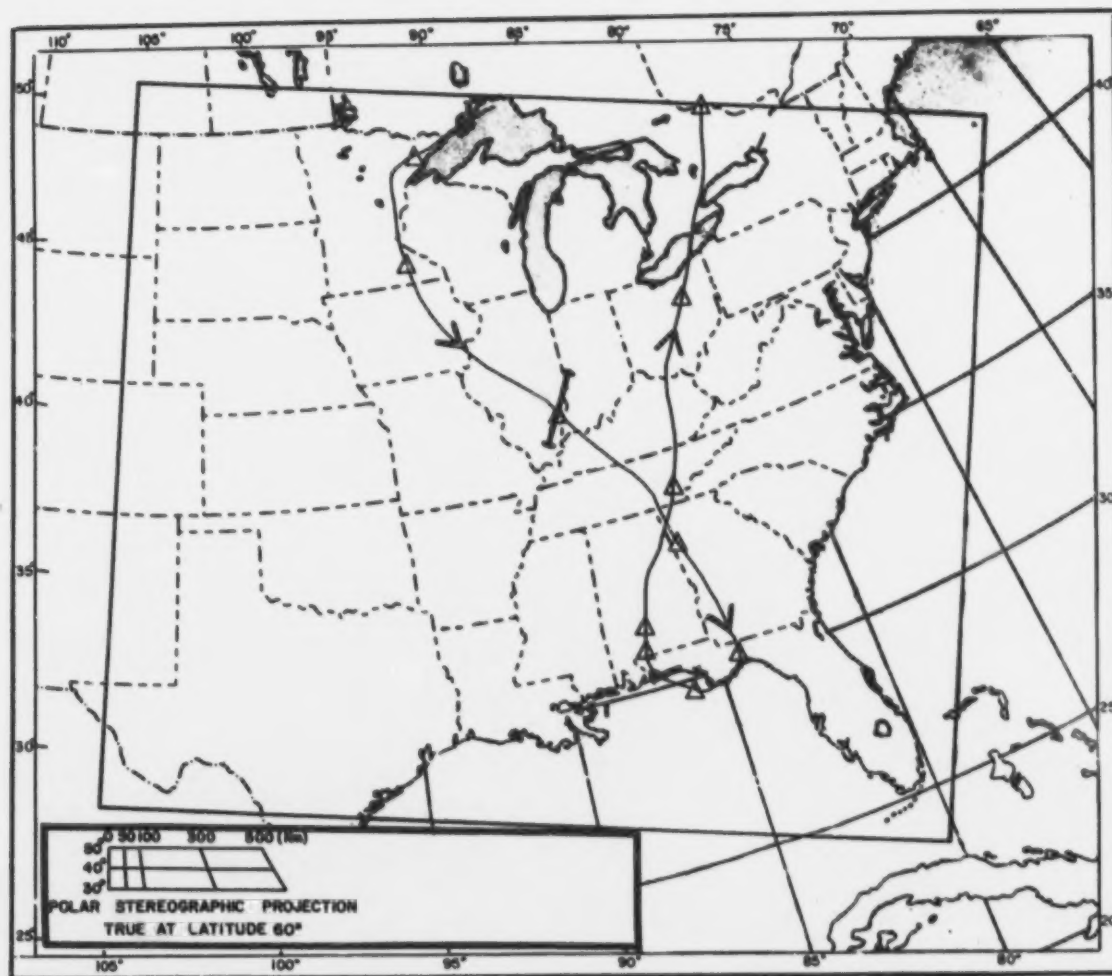
APRIL 5, 1980

The synoptic pattern on this day was characterized by a large area of high pressure. Skies were generally clear throughout the day. Surface winds were generally light and variable. Area 2-wide temperatures ranged from morning lows of about -1°C to afternoon highs of about 16°C. The average inversion height in the morning was about 40 m AGL rising to about 1500 m AGL during the afternoon and then lowering to about 50 m AGL during the evening. Average wind velocities in the mixing layer were light and variable throughout the day. Figures E18 through E22 show the 1000 m MSL air parcel trajectories for this date.

APRIL 15, 1980

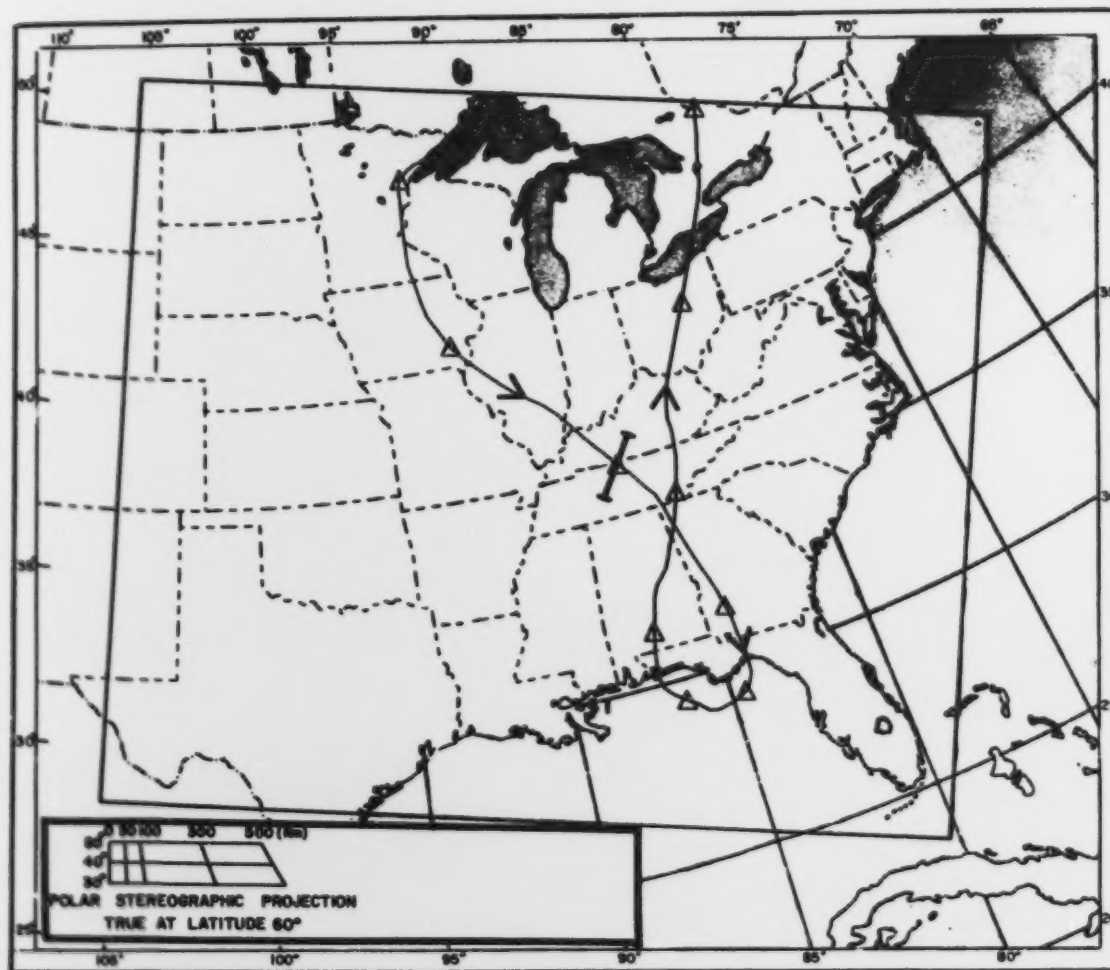
The synoptic pattern for this day was characterized by a cold front located over northwest Illinois, Iowa, and into Nebraska at 0700 CST which moved rapidly southwest during the day. Associated frontal weather over study area 2 consisted of low overcast stratus ceilings and scattered light rain and rain showers. Precipitation amounts over the area averaged less than 0.6 cm. Surface winds were generally west to west-northwest. Area-wide afternoon high temperatures averaged about 13°C. The average afternoon mixing height was above 1800 m AGL. Average wind speeds in the mixing layer were 9-13 m s⁻¹. The 1000 m MSL air parcel trajectories for the airborne sampling are shown in figures E23 and E24.

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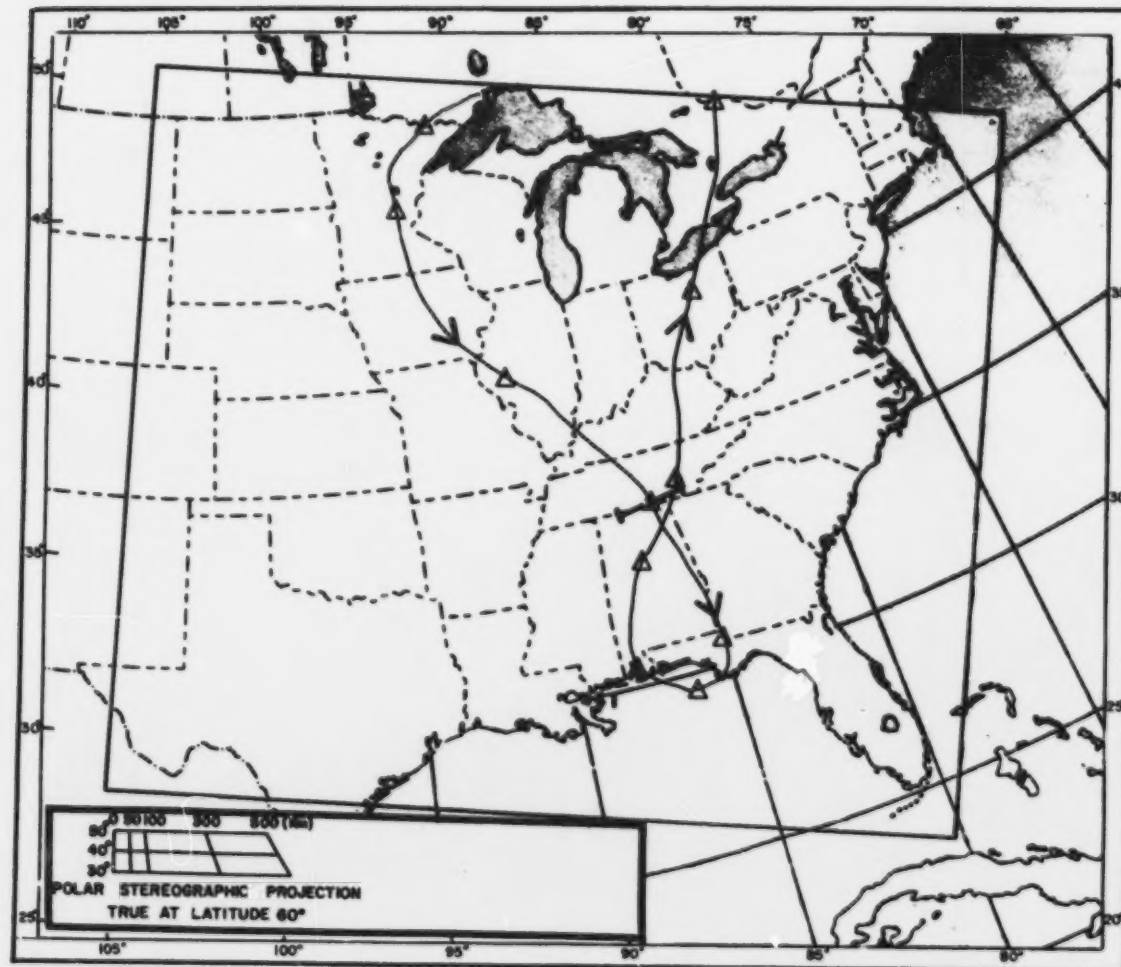
1,000 m MSL trajectory (12h intervals between triangles) 4/03/80 1300 CST to 4/08/80 1200 CST and aircraft sampling path (—|—) 4/04/80 2038-2134 CST.

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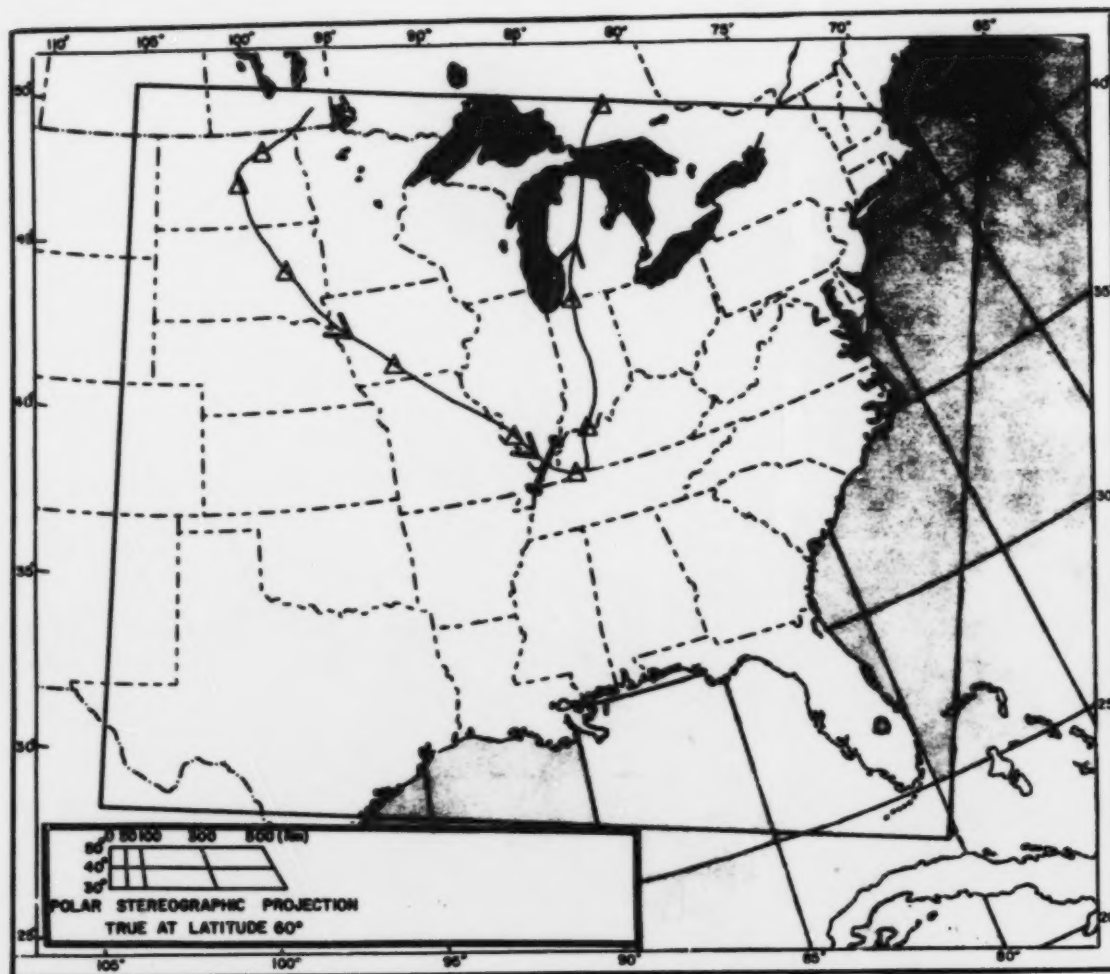
1,000 m MSL trajectory (12h intervals between triangles) 4/03/80 1100 CST to 4/08/80 1300 CST and aircraft sampling path (|—|) for 4/04/80 2350 CST - 4/05/80 0153 CST.

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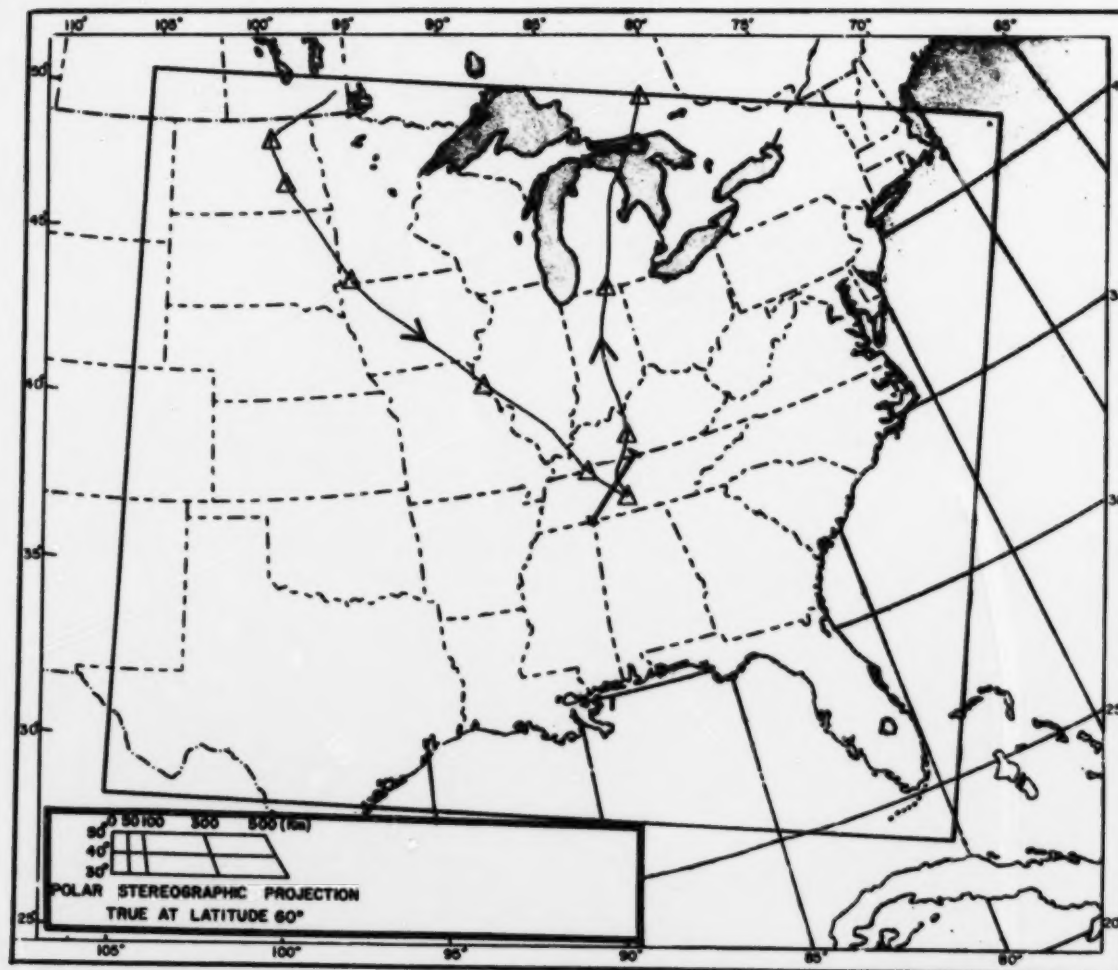


1,000 m MSL trajectory (12h intervals between triangles) 4/03/80 1100 CST to 4/08/80 1200 CST and aircraft sampling path (---) 4/05/80 0411-0503 CST.

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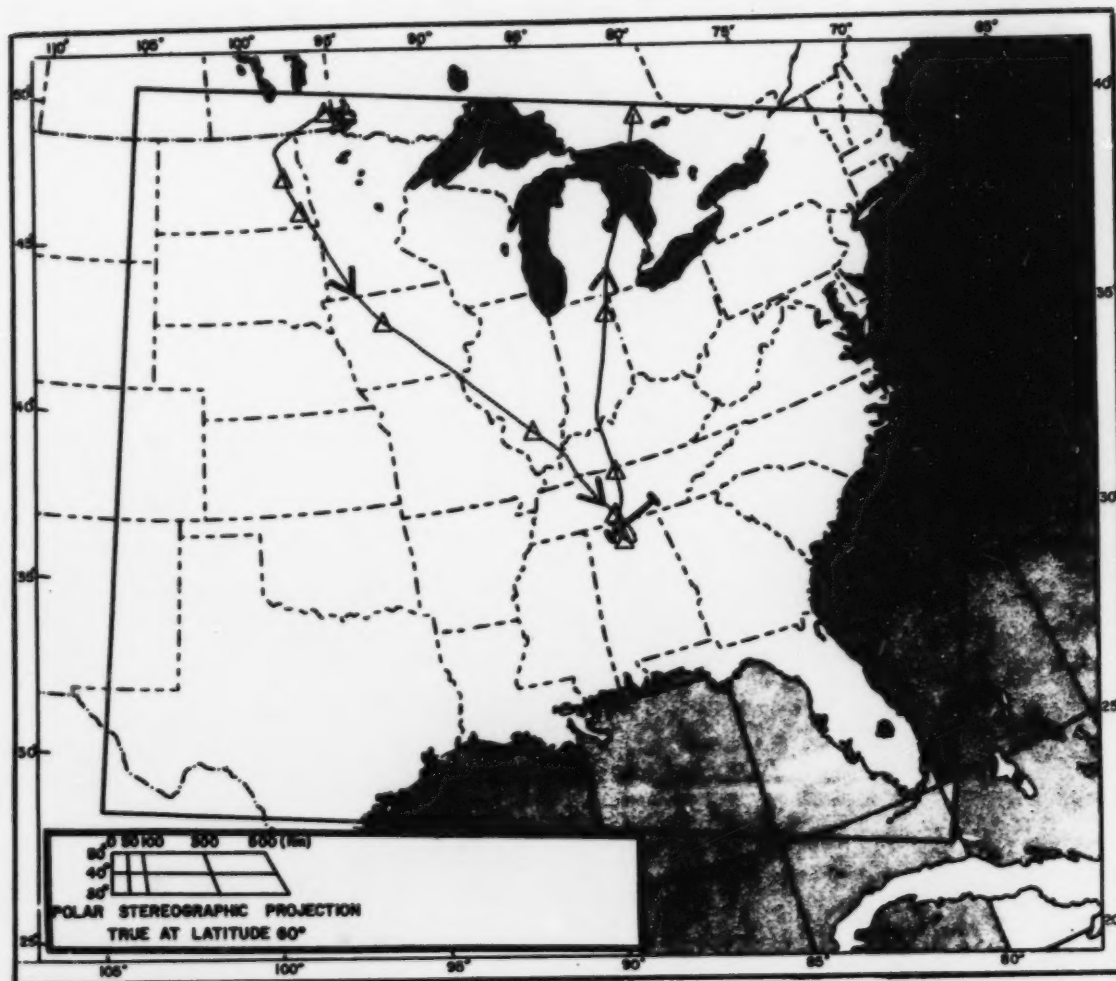
1,000 m MSL trajectory (12h intervals between triangles) 4/03/80 0200 CST to 4/07/80 0600 CST and aircraft sampling path (|—|) 4/05/80 0921-1148 CST.



1,000 m MSL trajectory (12h intervals between triangles) 4/03/80 0600 CST to 4/07/80 1100 CST and aircraft sampling path (|—|) 4/05/80 1436-1727 CST.

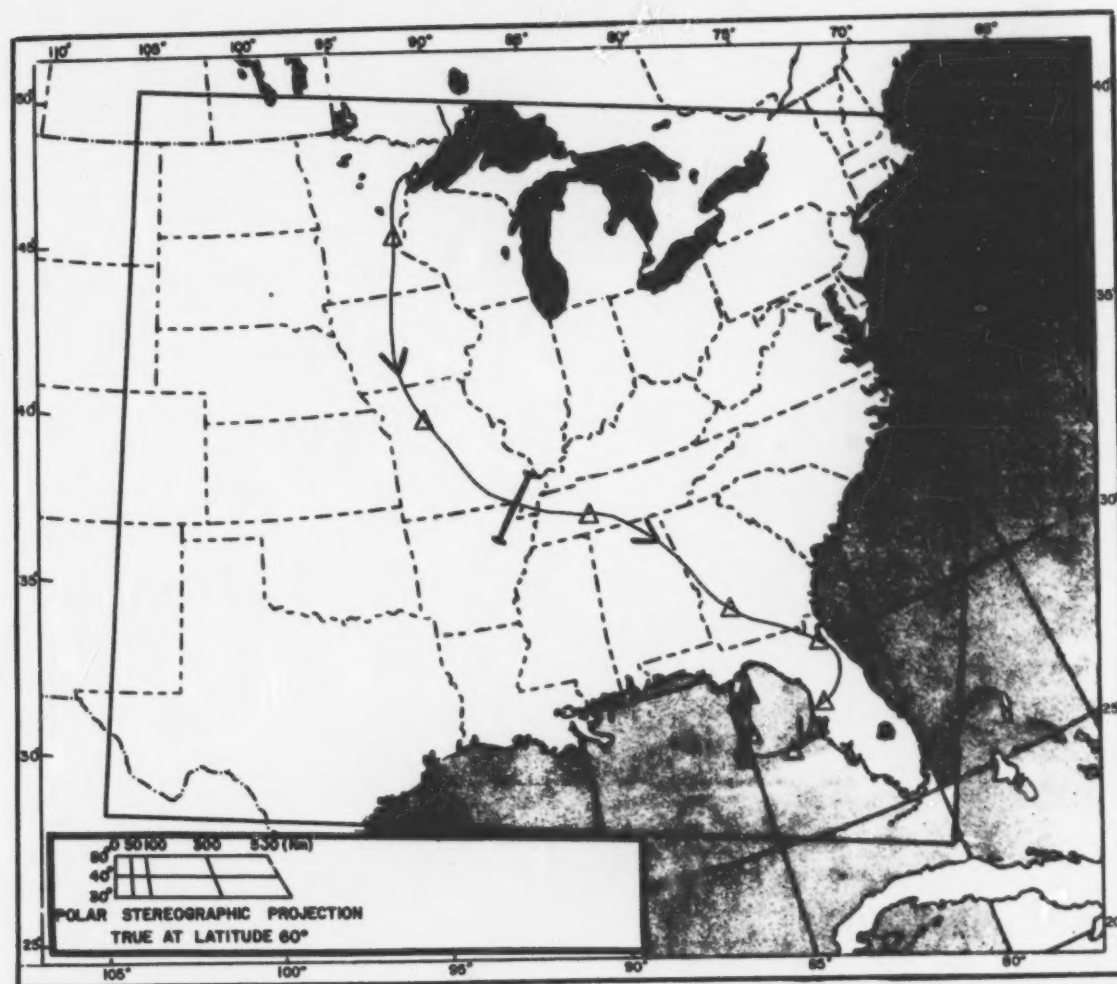
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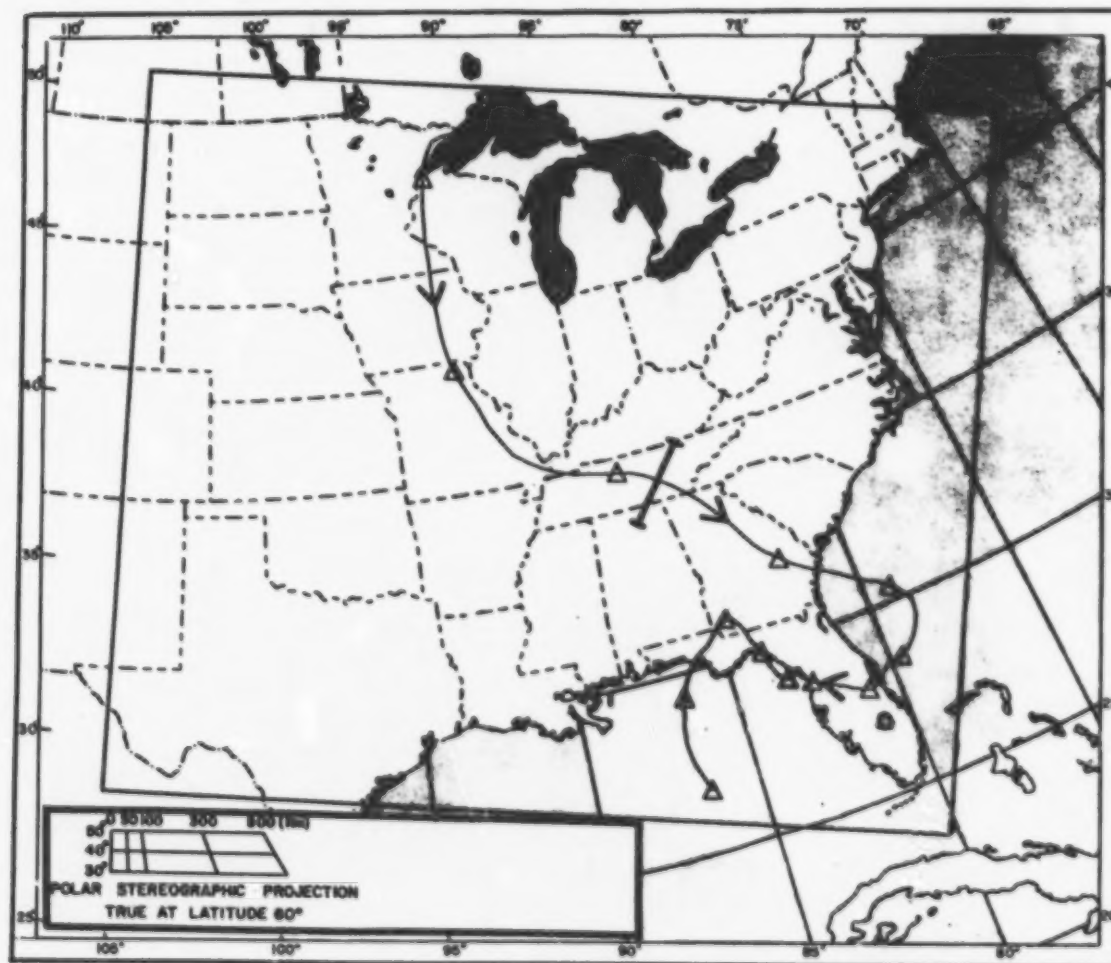


1,000 m MSL trajectory (12h intervals between triangles) 4/03/80 0800 CST to 4/07/80 1400 CST and aircraft sampling path (---) 4/05/80 1959-2236 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 4/13/80 1200 CST to 4/20/80 1000 CST and aircraft sampling path (---) 4/15/80 1129-1401 CST.



1,000 m MSL trajectory (12h intervals between triangles) 4/14/80 0600 CST to 4/20/80 1600 CST and aircraft sampling path (—) 4/15/80 1959-2218 CST.

APRIL 16, 1980

The synoptic pattern on this date was characterized by high pressure over the area. This system drifted southeast toward the mid-Atlantic coast. A Pacific frontal system was located west of study area 2. Skies were generally clear with surface winds varying from northwest to northeast. Area-wide temperatures ranged from morning lows of about 1°C to afternoon highs of about 18°C. The average mixing height in the morning was about 400 m AGL rising to about 1550 m AGL by afternoon. Average wind speeds in the mixing layer were 2-3 m s⁻¹ in the morning increasing to 5-7 m s⁻¹ by afternoon. Figure E25 shows the 1000 m MSL air parcel trajectory.

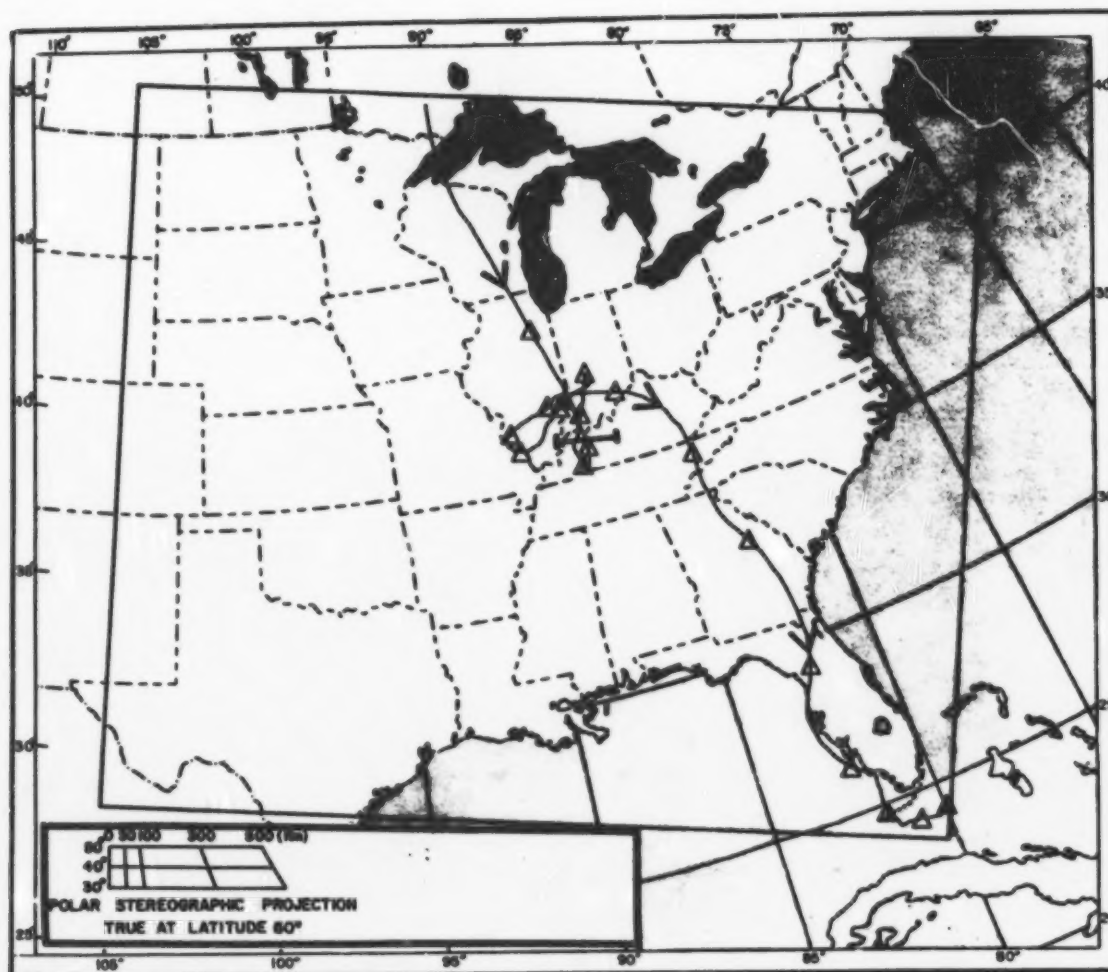
APRIL 17, 1980

The synoptic pattern on this day was characterized by a Pacific cold front extending southwest from a low in Kansas through Arkansas into central Mississippi. This system moved southeastward during the day thus staying south of study area 2. Weather over the study area was characterized by generally partly cloudy skies and east-northeast to southeast surface winds. Some broken cloudiness was observed along the western boundary of the study area. Area-wide temperatures averaged about 3°C for the morning low. Morning mixing heights averaged around 1200 m AGL. Average winds in the boundary layer were 3-6 m s⁻¹ during the morning. Figures E26 and E27 show the 1000 m MSL air parcel trajectories.

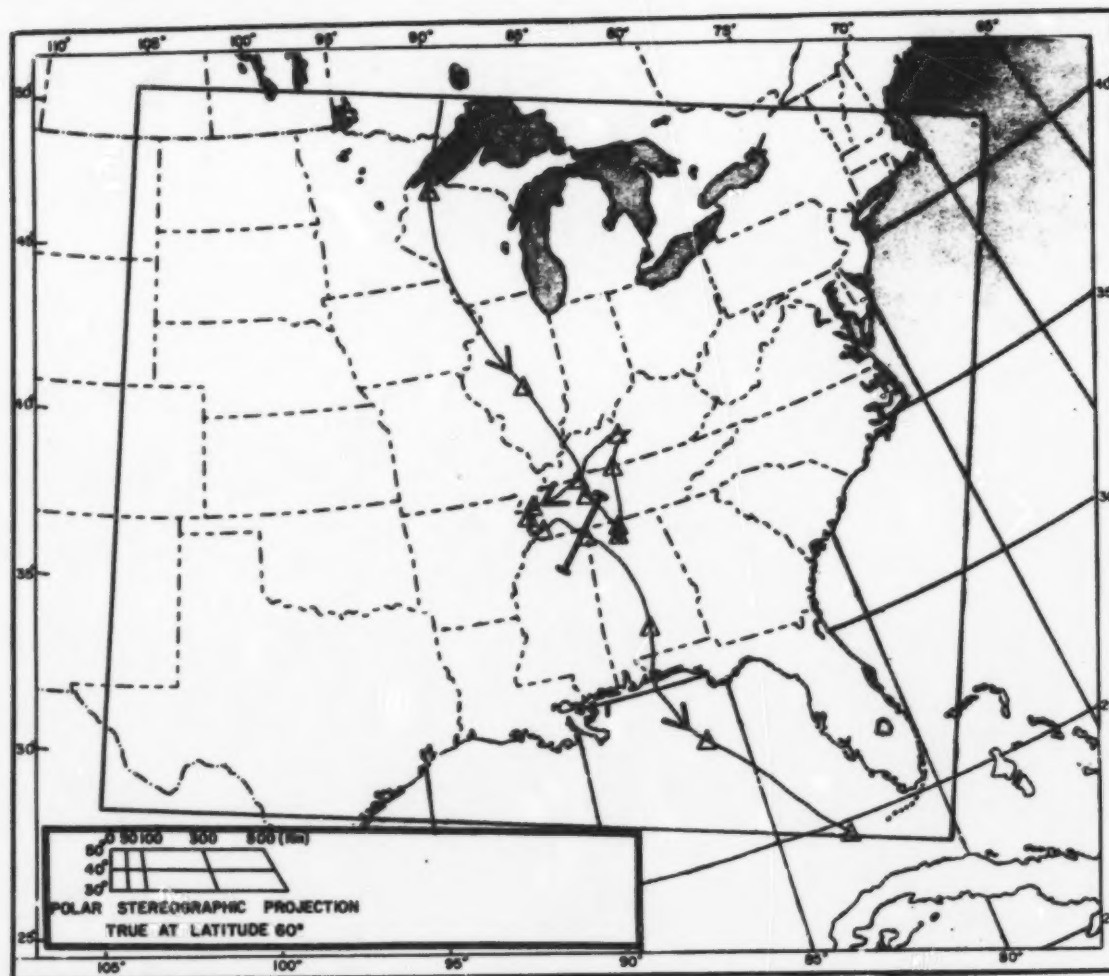
APRIL 19, 1980

The synoptic pattern on this day was characterized by high pressure over Arkansas-Mississippi area and a cold front in the Gulf. Prevailing

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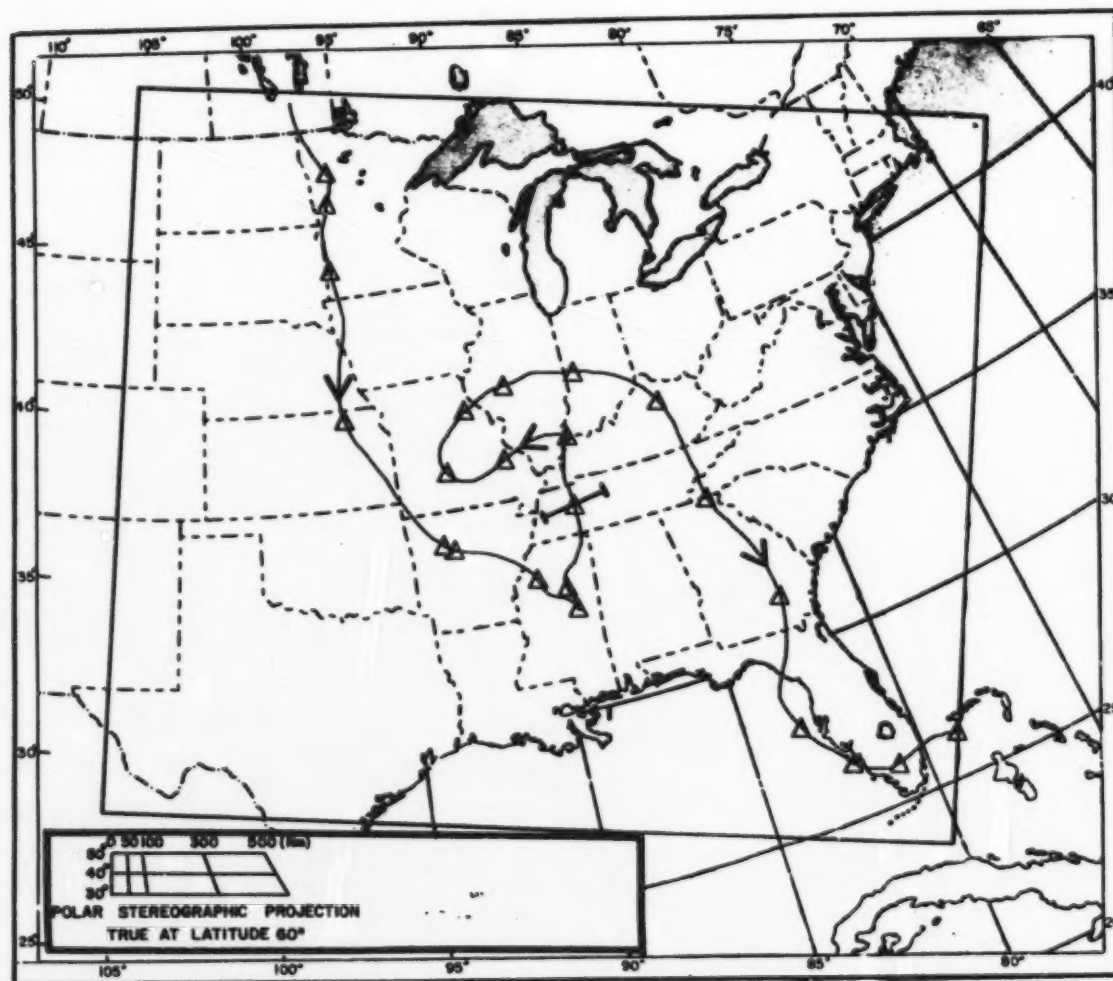
1,000 m MSL trajectory (12h intervals between triangles) 4/15/80 0800 CST to 4/24/80 0100 CST and aircraft sampling path (---) 4/16/80 0942-1132 CST.



1,000 m MSL trajectory (12h intervals between triangles) 4/15/80 0300 CST to 4/22/80 0000 CST and aircraft sampling path (—) 4/17/80 0643-0910 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 4/13/80 0500 CST to 4/23/80 2200 CST and aircraft sampling path (|—|) 4/17/80 1438-1523 CST.

weather conditions over study area 1 consisted of mostly cloudy skies with afternoon rainshowers and thundershowers. Precipitation across the area averaged about 1.3 cm with local high spots of 2.5 cm. Surface winds were generally northeast. Area-wide afternoon high temperatures averaged about 23°C. Average afternoon mixing was above 1600 m AGL. Average afternoon wind speeds in the mixing layer were 6-9 m s⁻¹. Figures E28 and E29 show the 1000 m MSL air parcel trajectories.

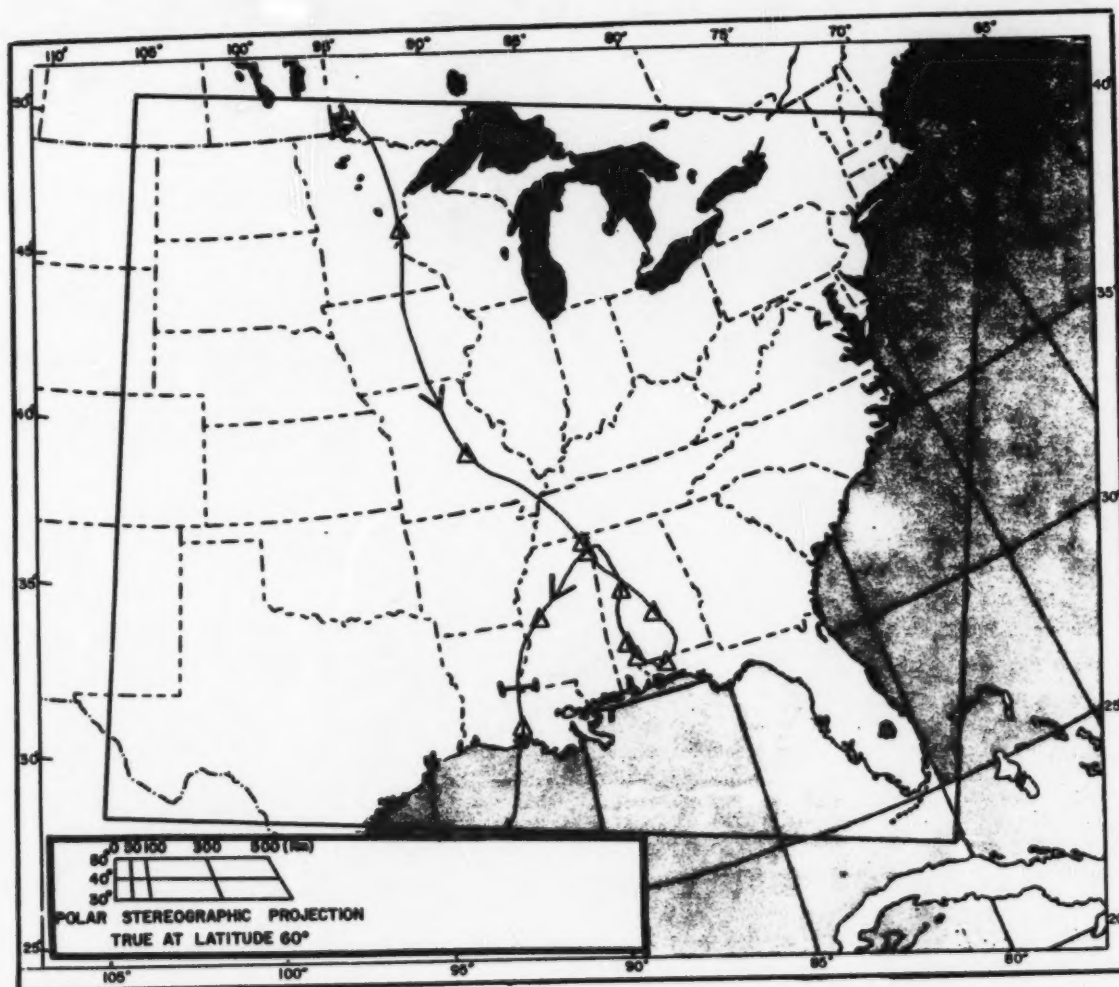
APRIL 20, 1980

High pressure dominated study area 1 on this day. Skies were generally clear and surface winds light and variable. Area-wide temperatures ranged from about 11°C for the morning low to about 27°C for the afternoon high. Average inversion heights were about 250 m AGL in the morning rising to about 2000 m AGL by afternoon. Average wind speeds in the boundary layer were about 4-8 m s⁻¹. The 1000 m MSL air parcel trajectories are presented in figures E30 and E31.

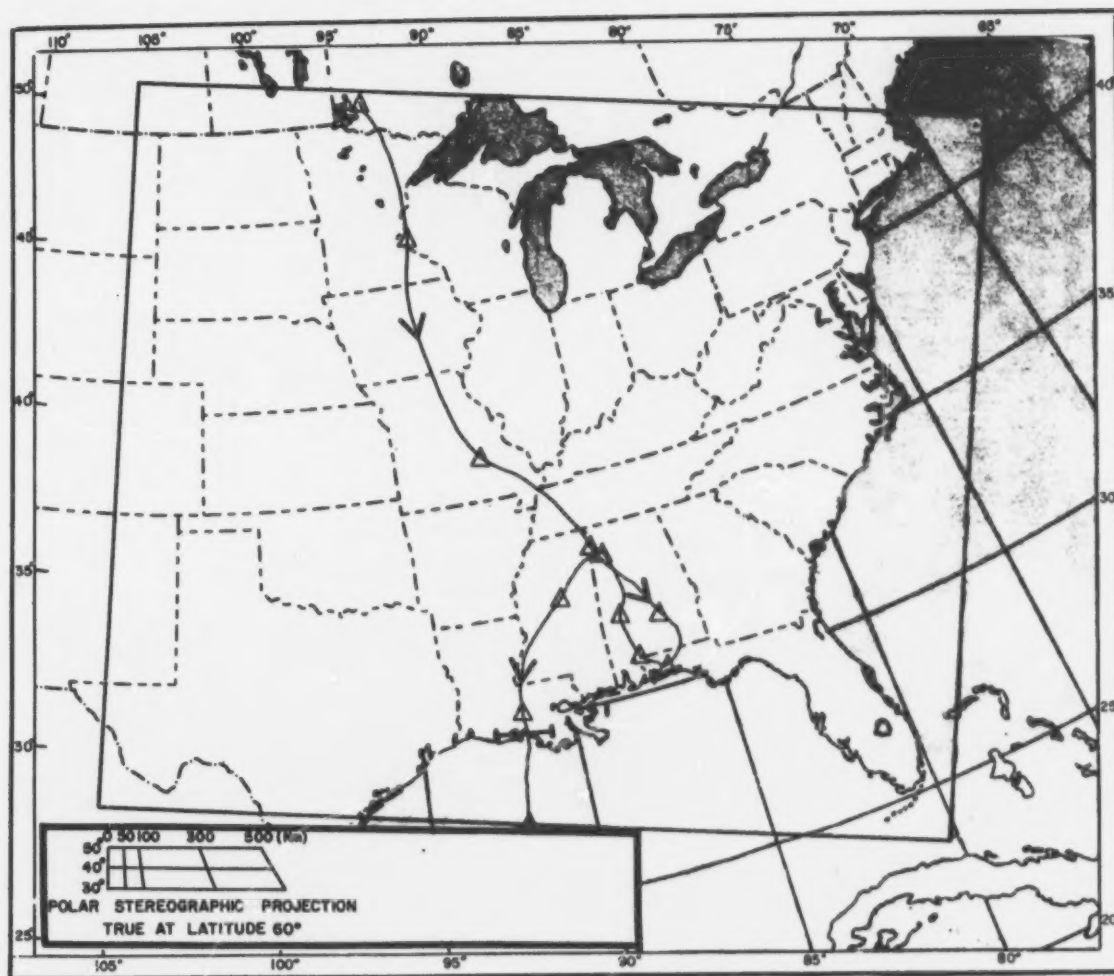
APRIL 21, 1980

The synoptic pattern on this day continued to be dominated by high pressure centered over Louisiana. Skies were generally clear to partly cloudy and surface winds were light from the west-southwest. Area 1-wide temperatures ranged from morning lows of about 13°C to afternoon highs about 30°C. Average mixing heights were above 2000 m AGL. Average wind speeds in the mixing layer were 2-4 m s⁻¹ in the morning increasing to 3-6 m s⁻¹ by afternoon. Figures E32 through E34 show the 1000 m MSL air parcel trajectory.

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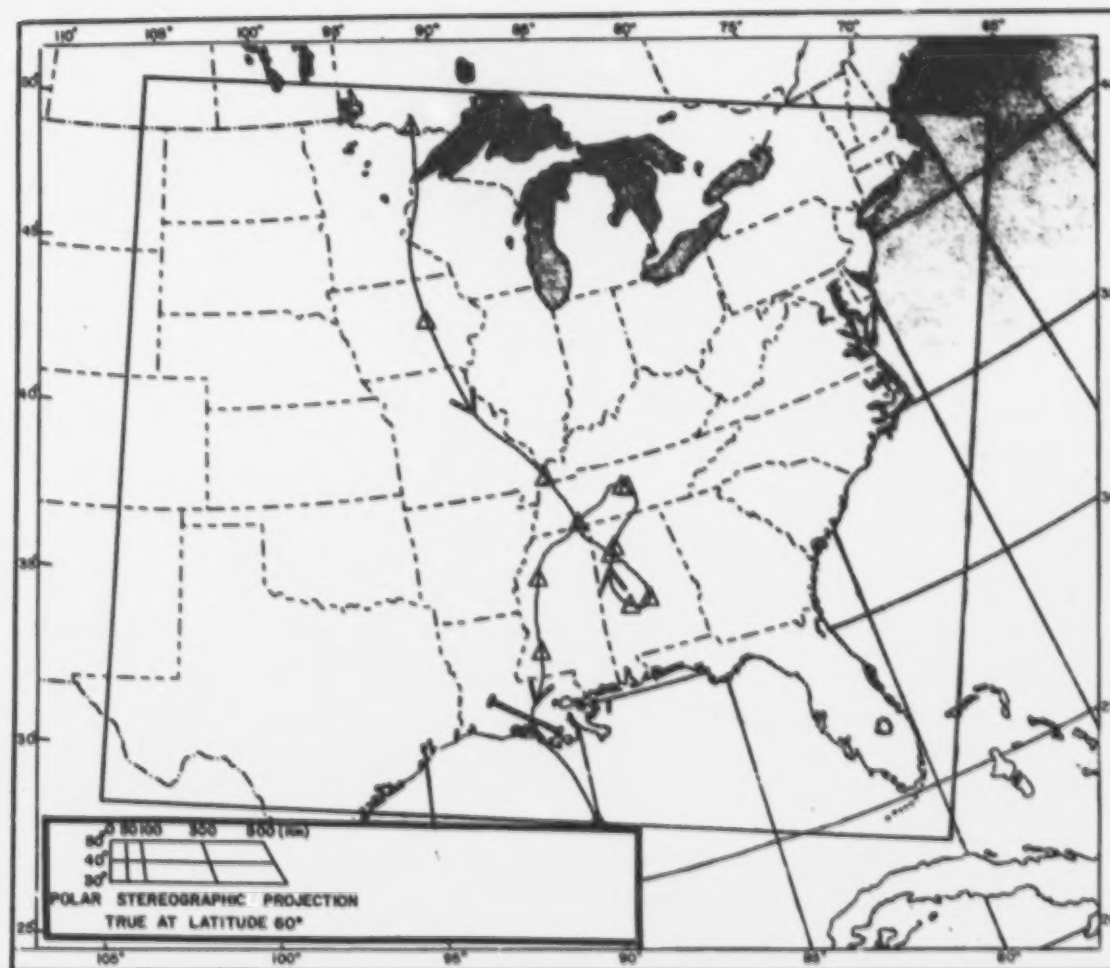
1,000 m MSL trajectory (12h intervals between triangles) 4/14/80 1600 CST to 4/20/80 0700 CST and aircraft sampling path (---) 4/19/80 1411-1620 CST.



1,000 m MSL trajectory (12h intervals between triangles) 4/14/80 1600 CST to 4/20/80 0400 CST and aircraft sampling path (—) 4/19/80 1749-2018 CST.

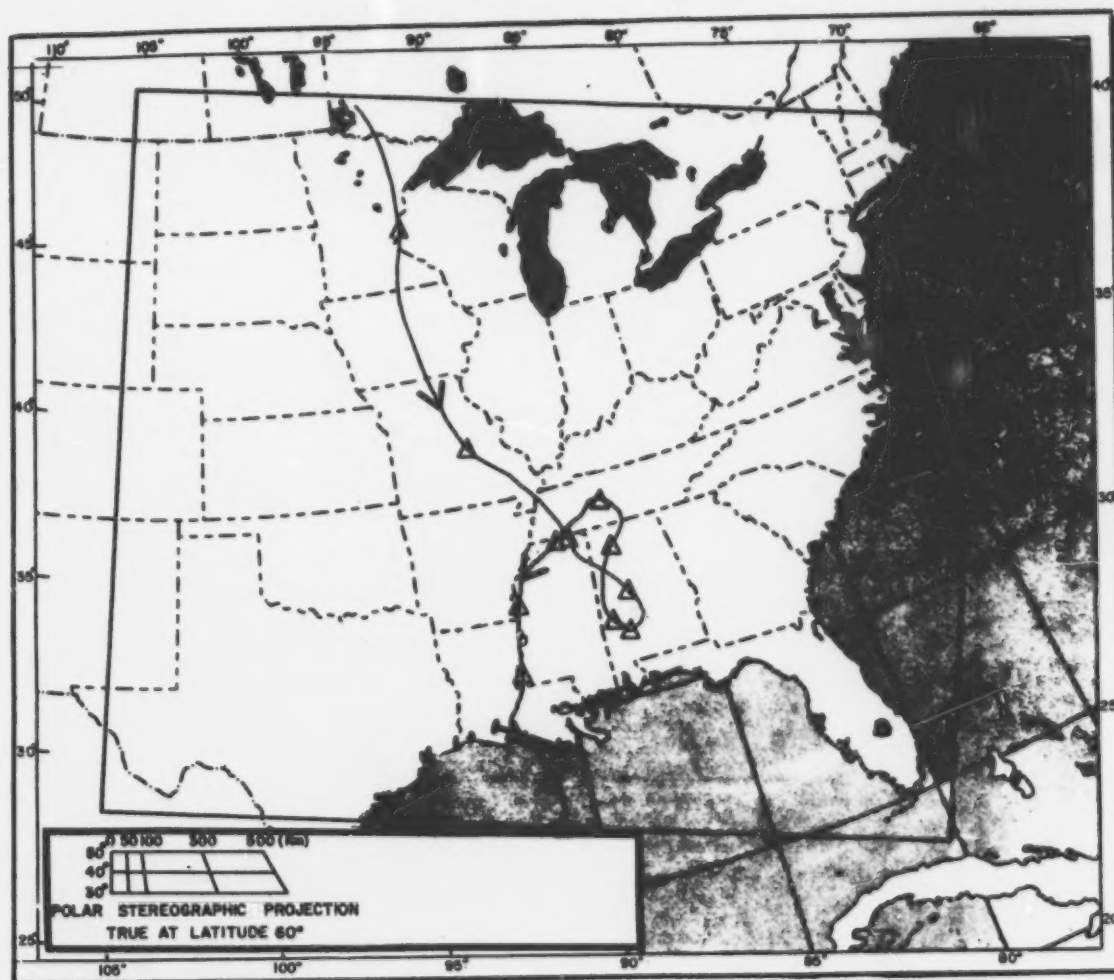
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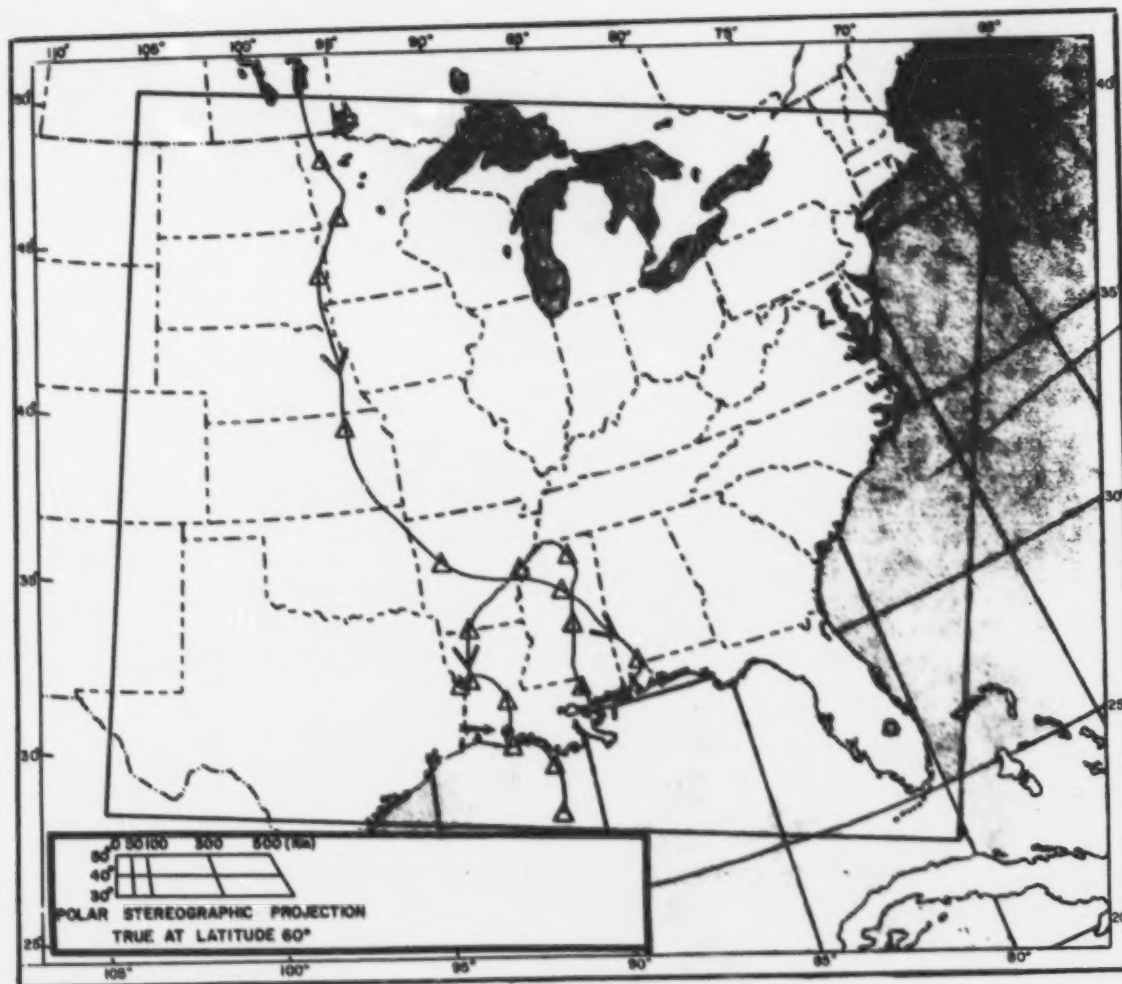
1,000 m MSL trajectory (12h intervals between triangles) 4/14/80 2200 CST to 4/21/80 0100 CST and aircraft sampling path (—|—) 4/20/80 0952-1156 CST.

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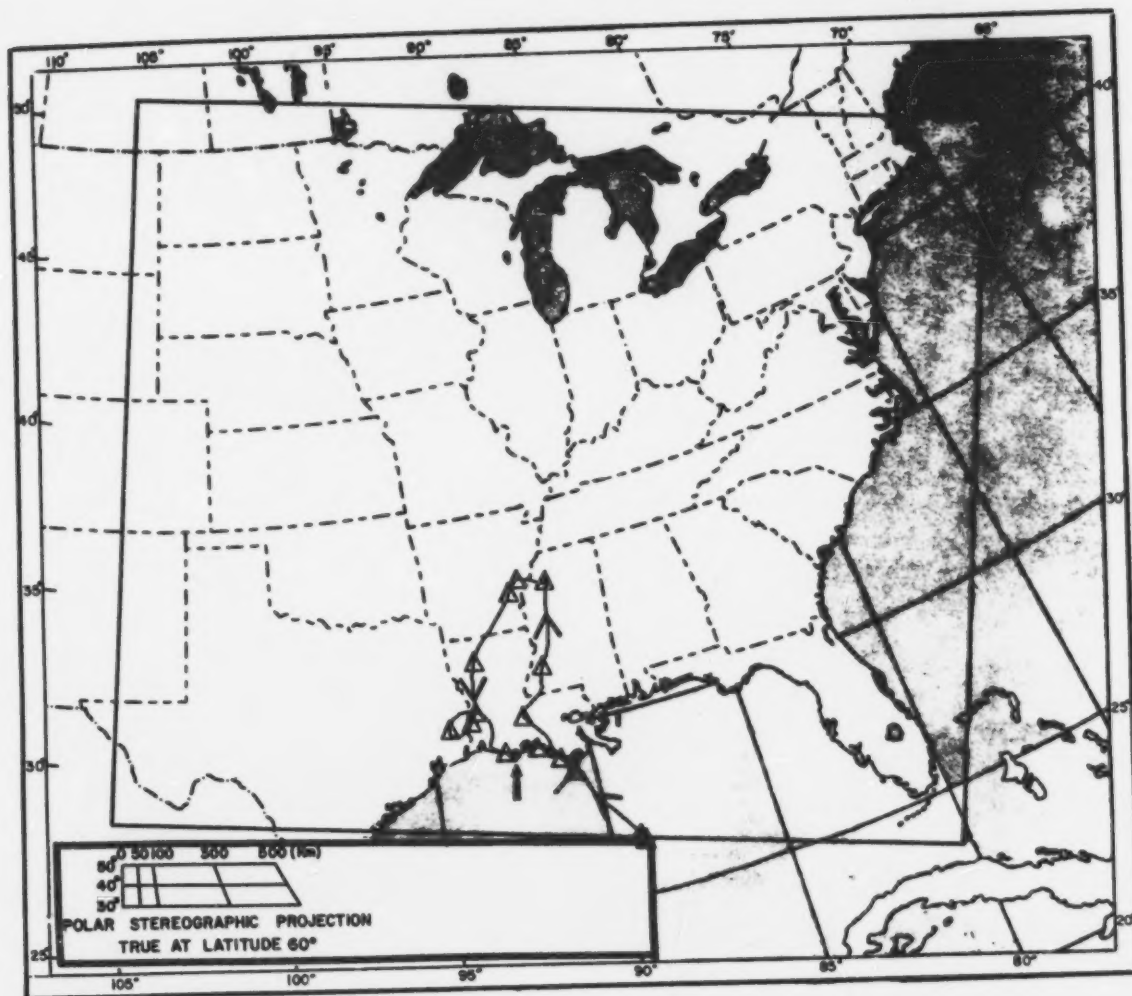
1,000 m MSL trajectory (12h intervals between triangles) 4/14/80 1700 CST to 4/21/80 0200 CST and aircraft sampling path (—) 4/20/80 1515-1803 CST.

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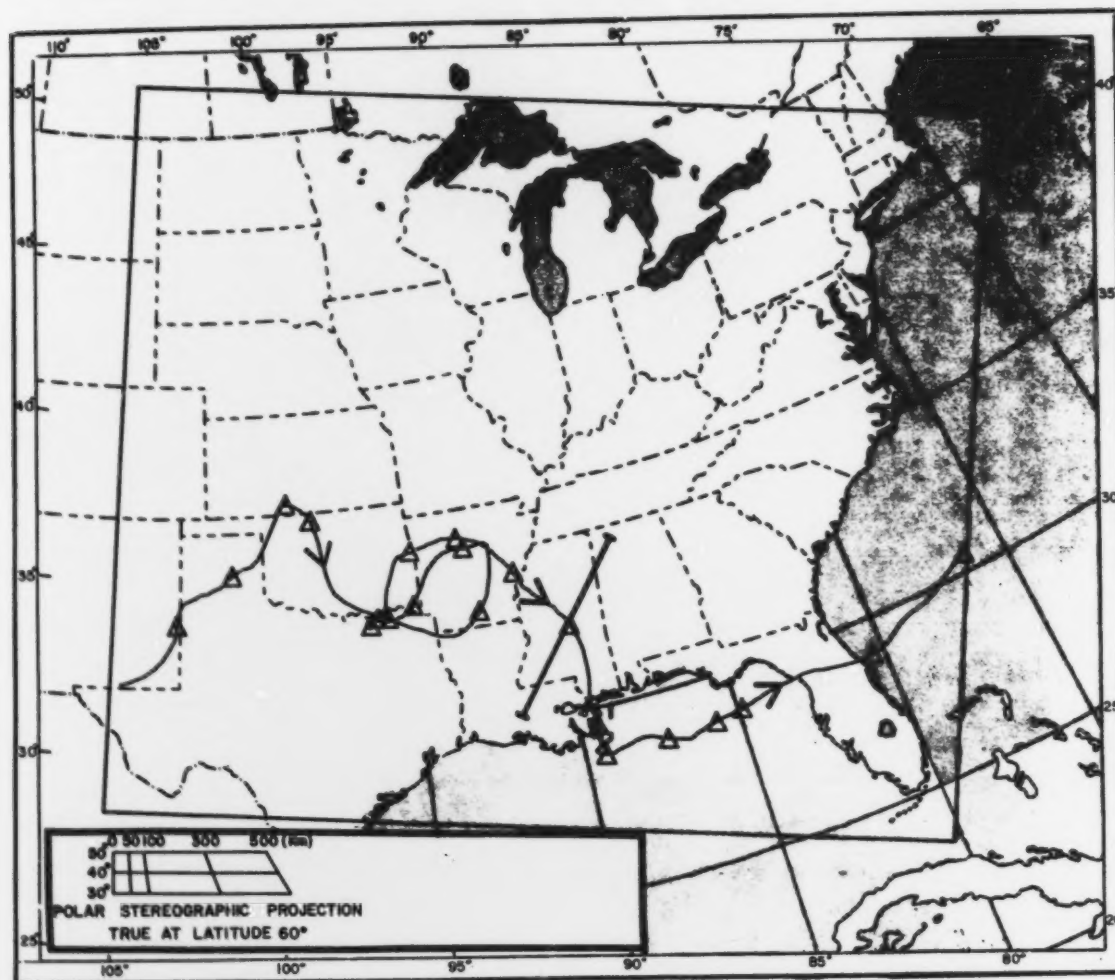
1,000 m MSL trajectory (12h intervals between triangles) 4/13/80 0400 CST to 4/22/80 0600 CST and sampling location (•) 4/21/80 1016-1247 CST.

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305 m MSL trajectory (12h intervals between triangles) 4/16/80 0100 CST to 4/22/80 0800 CST and aircraft sampling location (•) 4/21/80 1438-1630 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 4/15/80 0800 CST to 4/24/80 2300 CST and aircraft sampling path (—○—) 4/21/80 1836-2036 CST.

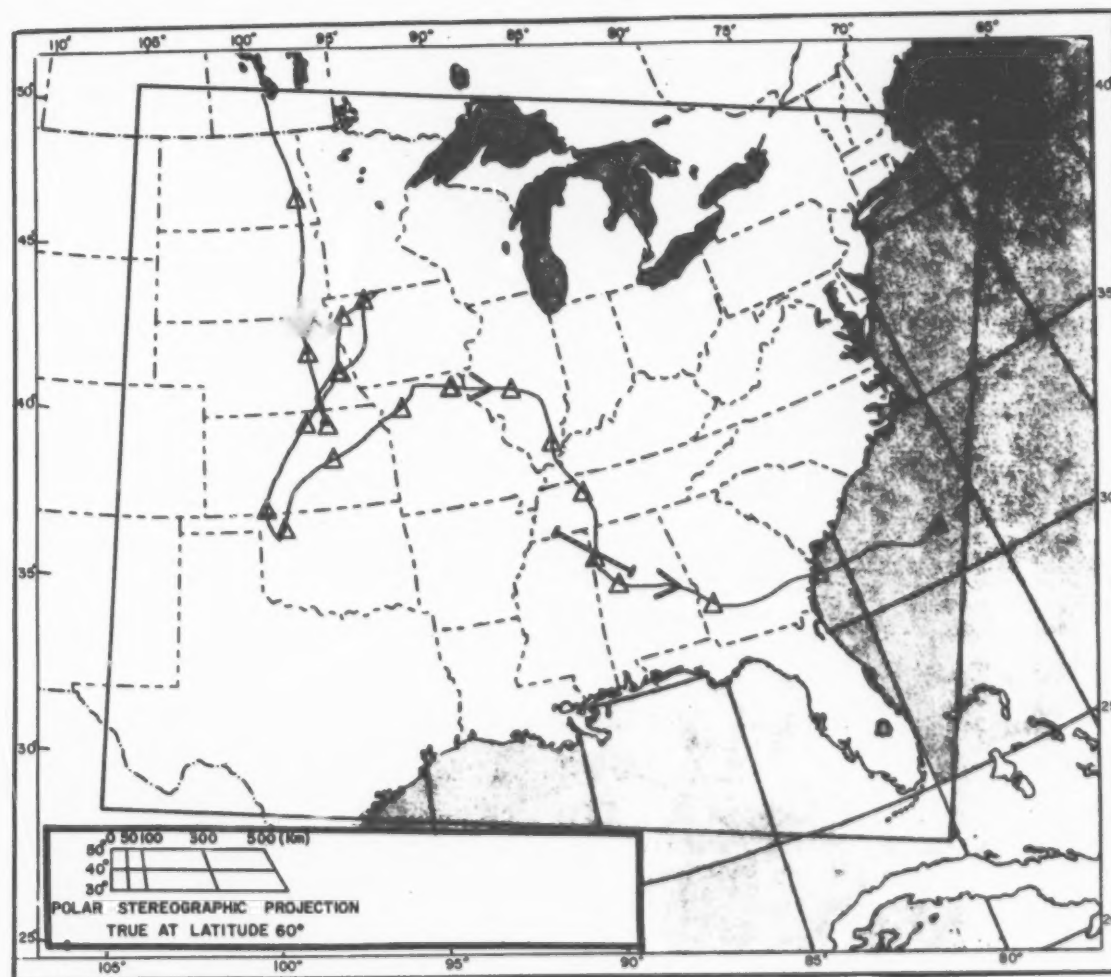
APRIL 22, 1980

The synoptic pattern on this day was characterized by a weak front extending from Illinois through western Tennessee into Mississippi and Alabama. This front dissipated during the day. Skies were generally partly cloudy over both study areas. Surface winds were light and variable. Area-wide temperatures ranged from morning lows of about 12°C in area 1 and about 8°C in area 2 to afternoon highs of about 30°C in both areas. Average inversion heights in the morning were about 100 m AGL in area 1 and about 70 m AGL in area 2 rising to about 1150 m AGL in area 1 and above 2000 m AGL in area 2 by afternoon. Average wind speeds in the mixing layer were 3-4 m s⁻¹ in area 1 and 3-6 m s⁻¹ in area 2 during the morning and remained light throughout the day. Figure E35 shows the 1000 m MSL air parcel trajectory.

APRIL 23, 1980

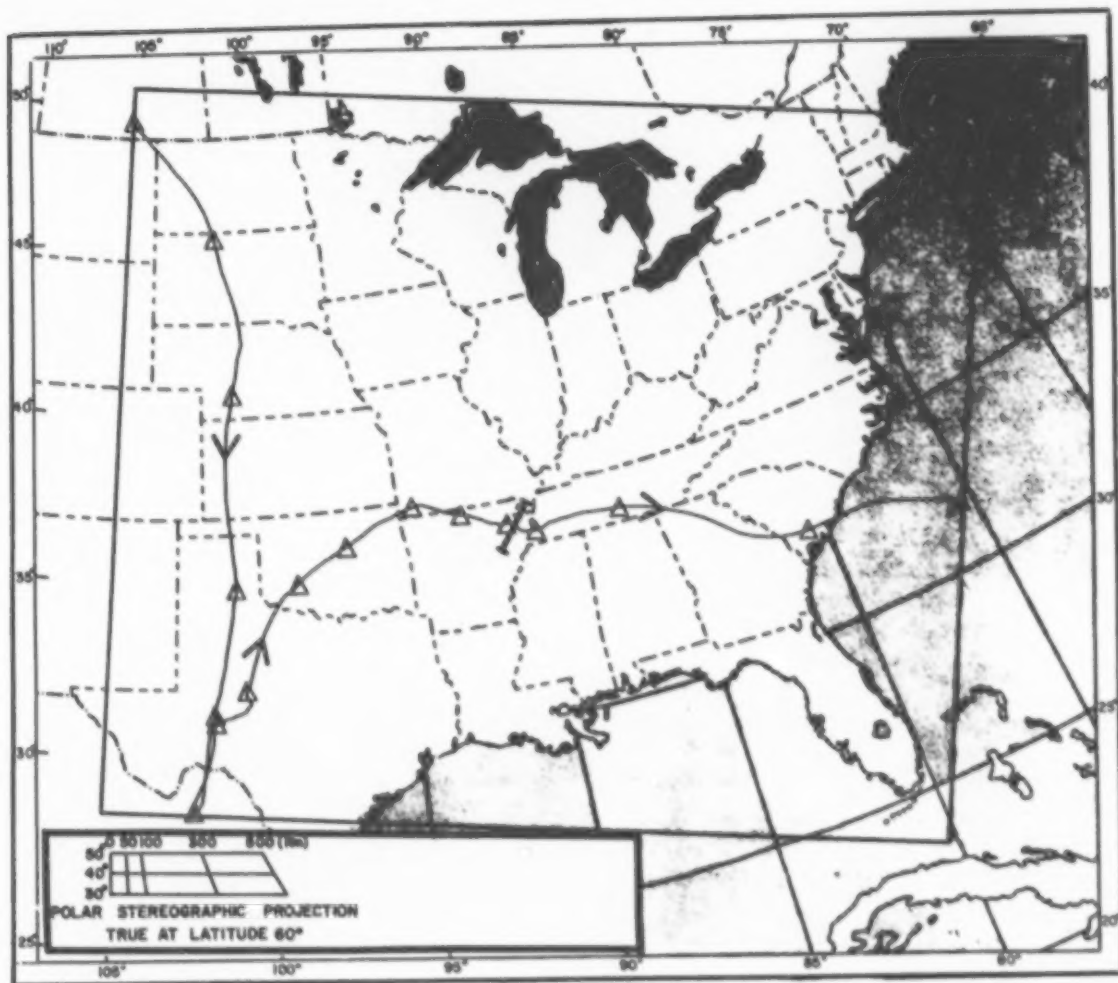
The synoptic pattern on this day was characterized by a weak cold front across northern Kentucky, southern Illinois and westward. This frontal system moved slowly south through study area 2 during the day. Skies over the study area were generally partly cloudy and surface winds were southwest. Area-wide temperatures averaged about 18°C in the north and about 14°C in the south for morning lows rising to about 30°C for average afternoon highs over the entire study area. Inversion heights in the study area averaged about 1500 m AGL in the morning rising above 2000 m AGL by afternoon. Average wind speeds in the mixing layer were about 2-4 m s⁻¹ during the morning becoming 4-6 m s⁻¹ by afternoon. The 1000 m MSL air parcel trajectories are shown in figures E36 through E38.

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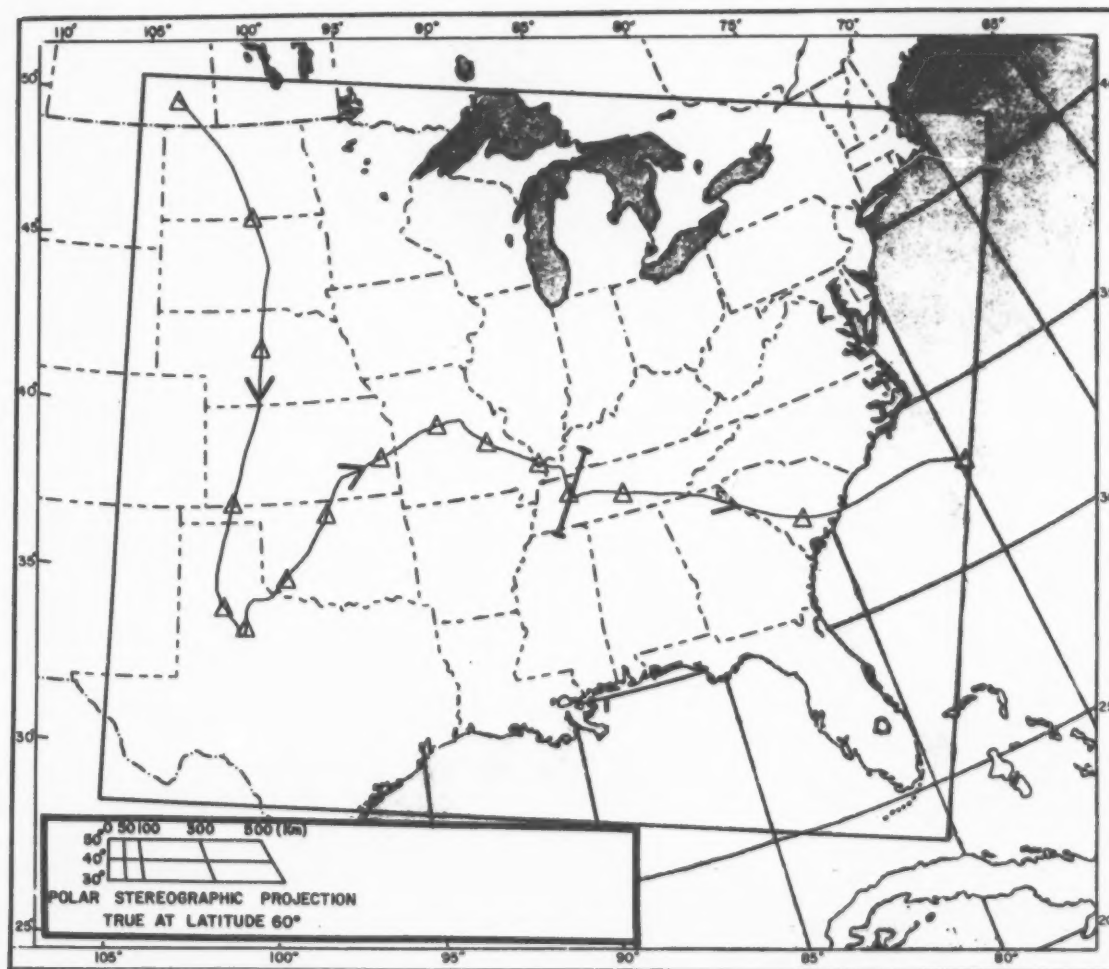
1,000 m MSL trajectory (12h intervals between triangles) 4/14/80 1300 CST to 4/24/80 1000 CST and aircraft sampling location (—) for 4/22/80 0850-1156 CST.

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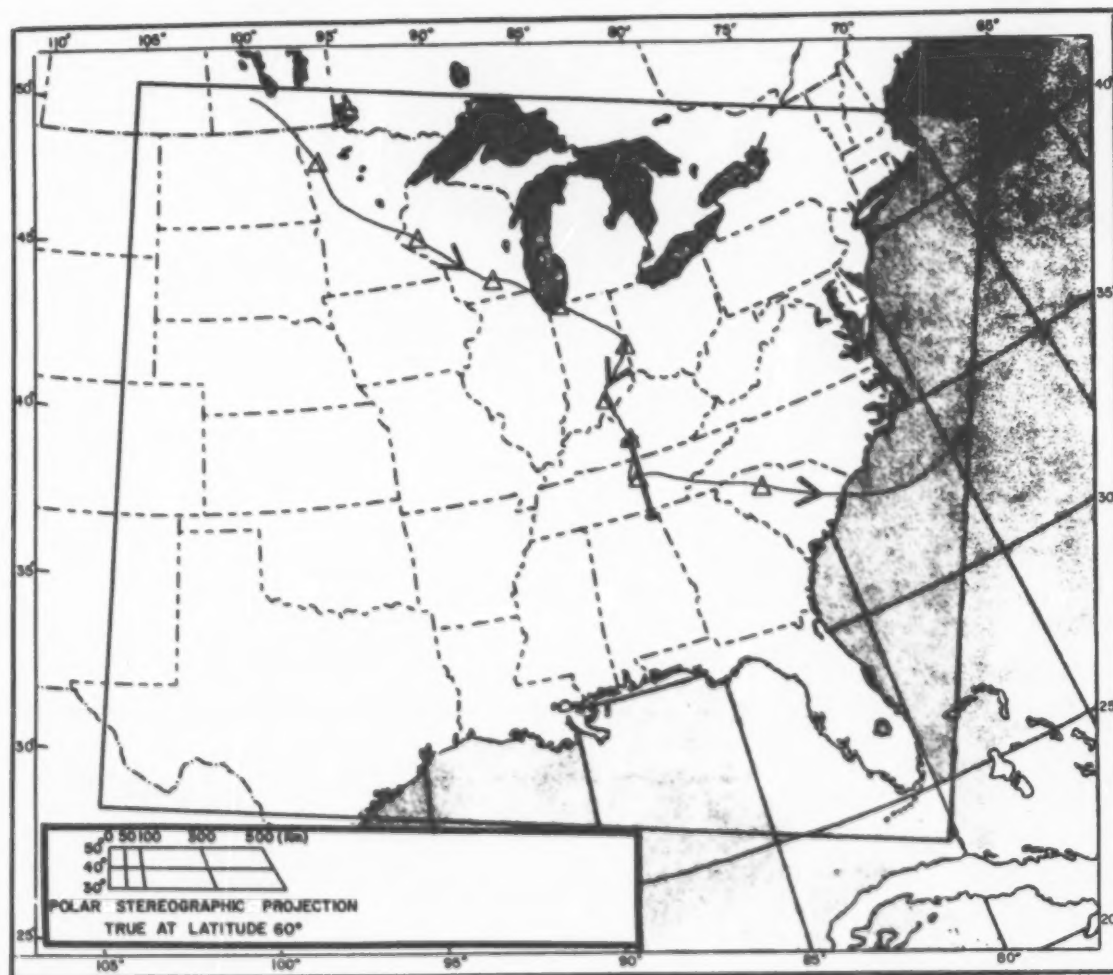
1,000 m MSL trajectory (12h intervals between triangles) 4/16/80 0800 CST to 4/24/80 0300 CST and aircraft sampling path (---) 4/23/80 0711-0917 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 4/16/80 1200 CST to 4/23/80 2300 CST and aircraft sampling path (—|—) 4/23/80 1112-1324 CST.

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1,000 m MSL trajectory (12h intervals between triangles) 4/18/80 2100 CST to 4/23/80 1700 CST and aircraft sampling path (—) 4/23/80 1602-1805 CST.